Utilization of

Textile Wastes Seminar

June 20 – 21, 1977

Victory Hall
Queen's University
Kingston, Ontario

Ministry of Industry and Tourism

Ministry of the Environment

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PREFACE

SEMINAR ON

UTILIZATION OF TEXTILE WASTE

IN ONTARIO

Due to the increasing problems in the disposal of textile waste and the increasing concern for better utilization of our resources, it was decided to convene a seminar to explore the problem and examine our opportunities for useful conversion of waste to assets.

The extent and location of textile waste products was explored in depth and a series of opportunities for exploiting this material was presented to Ontario business people. New areas of research and methods were brought forward which showed the manufacturing opportunities available and the dollar earning potential of utilizing waste textile materials.

This seminar was sponsored by the Ministry of Industry and Tourism in co-operation with the Ministry of the Environment.

H. P. Smith

Industry Branch

October, 1977

May 11, 1977

UTILIZATION OF TEXTILE WASTES SEMINAR

JUNE 20 - 21 1977

VICTORY HALL

QUEEN'S UNIVERSITY

KINGSTON, ONTARIO

Monday - June 20th, 1977

17:00	Hours	Registration
18:00	Hours	Cash Bar
18:30	Hours	Dinner
19:30	Hours	"Analysis of Ontario Textile Wastes" Dr. M. J. Williams, Assistant Director, Dept. of Textiles Clothing & Footwear, Ontario Research Foundation.
20:00	Hours	"Textiles From Waste Fibres" Mr. Richard Mortimer, Associate Research Scientist, Ontario Research Foundation.
20:30	Hours	Discussion
		Adjournment

Tuesday - June 21st, 1977

08:30	Hours	Registration
09:00	Hours	Introduction
09:05	Hours	"A New Use For Man-Made Fibre Waste" The Science of Microcrystaline Polymers, Dr. A. O. Battista, President, Research Services Corporation, Forth Worth, Texas
09:50	Hours	"Energy Recovery From Textile Wastes" Dr. R. G. W. Laughlin, Assistant Director, Dept. of Environmental Chemistry, Ontario Research Foundation.
10:15	Hours	Coffee
10:45	Hours	"Better Utilization of Textiles" N. Eberly, Director, Kurt Salmon Associates, Atlanta, GA.

Tuesday - June 21st, 1977 (Cont'd)

11.15	Hours	"Building Products From Carpet & Textile Wastes" Mr. Rolf Wagner, Syntex Chemie G.h.m.B., Germany.
12:00	Hours	Cash Bar
12:30	Hours	Lunch
		Dr. J. Kates Chairman, Science Councilor of Canada "The Conserver Society" The Challenge of The Seventies
14:00	Hours	"Industrial Waste Materials Exchanges" Dr. R. G. W, Laughlin, Ontario Research Foundation.
14:30	Hours	"Wipers From Waste" Mr. Cliff Palm, Omnitex Inc., Charlotte N.C.
15:00	Hours	A Panel Discussion On "Non-Textiles From Textile Waste" Mr. Jacob Leidener & Mr. W. D. Brown Ontario Research Foundation.
15:45	Hours	Wrap Up Mr. D. P. Dempster, Industrial Development Officer, Industry Branch, Ministry of Industry & Tourism.

ONTARIO RESEARCH FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY

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UTILIZATION OF TEXTILE WASTES

FINAL REPORT FOR

MINISTRY OF INDUSTRY & TOURISM

W. D. Brown
R.G.W. Laughlin
J. Leidner
R. A. Mortimer
M. J. Williams

April 29, 1977

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UTILIZATION OF TEXTILE WASTES

1.0 INTRODUCTION

The subject of textile waste utilization is one of the most significant and challenging problems confronting the entire textile manufacturing industry. Numerous studies have been made by individual companies, associations and institutes in Canada, U.S.A., U.K. and elsewhere, but all without satisfactory conclusion. On the basis of such studies, it can be concluded that, because of the diversified composition of waste cuttings and the technical development of the textile products industry, the solution of the problem may not lie within the textile industry itself. As little as five years ago, many garment manufacturers could expect to receive 5¢ per lb. for waste cuttings from scrap dealers and fibre recycling companies. Reuse applications included re-spinning, upholstering, and stuffing material, papermaking, wadding, and caulk filler, to mention a few. However, the industry trend to synthetics, multi-colours, permanent press and other special treatments, together with rising labour and transportation costs, has created technical and economic barriers to the use of cuttings in these conventional markets. As a result, most manufacturers today are forced to dump cuttings and waste and to pay haulage costs as well.

Currently, certain waste and substandard materials from Canadian mills can be, and is being, recycled. A substantial volume of fabric from Canadian mills and imported fabric waste (e.g. wool from U.K.) is shredded, pulled and recycled either by mills or felt manufacturers. Some wastes from the garment and mill industries are also being exported to low wage countries such as Spain, Greece, etc., where the cost of hand-sorting is not critical. However, even in this situation, cost of collection, baling, and shipping leaves little profit to the exporter.

Often the secondary fibre industry reprocesses millions of pounds of material (estimated 10-15 million pounds of material in Toronto area) but very little from the garment cutting trade. Faced with rising cost factors, stricter content requirements on new goods, competition from foam plastic in the upholstery trade and non-woven paper fibre replacing the cloth wiper market, the recyclers of textile fibre are in a critical period. Technologically, the fibre recyclers are handicapped and conversion from a labour intensive to a capital intensive industry is unlikely, if not impossible. It can be assumed that this segment of the industry is not going to play a major role in solving the garment and textile waste problem.

In order to put the problem into perspective, certain factors must be recognized as characteristic of the textile and apparel trade:

- Waste is generated in hundreds of establishments dispersed throughout Ontario.
- The amount of waste generated by one establishment is seldom, if ever, sufficient to justify conversion to a marketable product.
- The composition of the waste varies widely and is increasingly mixtures of synthetic and natural fibres with specialty finishes, or 100% synthetics.
- Utilization of wastes will have to be based on either a very high volume usage, probably with a relatively low value added price, or, alternatively, a low volume usage in a high value added product.
- The energy content of these wastes is comparable to coal, if not better (i.e. over 10,000 BTU per lb.). Energy resources are increasingly a national concern, and therefore the fact that a pound of fabric is approximately equivalent to a pound of conventional fuel should not be overlooked. Since this is a direct use possibility (at least for larger establishments), the BTU content as a replacement or supplementary fuel can be used as a value basis for this waste. The environmental impact of utilizing these wastes as substitute fuel should be considered in terms of pollution control requirements to meet regulatory standards.

With the above factors in mind, certain conclusions can be drawn. Firstly, there is a primary need to define waste collection procedures, to minimize handling and shipping costs, and to accumulate enough waste to justify any secondary product manufacture in the various geographical areas.

Secondly, the sort of product to be produced from these wastes is likely to be a composite material which will utilize the fibre or fabric qualities with a minimum of sorting, handling and re-working costs.

2.0 TEXTILE WASTE IN ONTARIO

The situation in Ontario today, is one of enormous wastage of material as can be seen from the following statistics which have been developed by the Ministry of Industry and Tourism. Table 1 relates specifically to textile waste and Table 2 to garment waste.

TABLE 1

ONTARIO TEXTILE WASTE SURVEY

Number of Firms Participating: 48

Waste Material	Sold to Dealers (lbs)	To Dump (lbs)
Sweeps	9,000	1,688,200
Yarn	4,846,890	4,230,054
Fabric	170,000	204,500
Roving	60,500	80,395
Carpet Trimmings	110,000	1,498,000
Other	33,000	234,000
Fabric Trimmings	217,921	341,400
	5,447,311	8,364,049
Cost of Dumping		$194,110.00
Received from Dealers	$362,933.31	

TABLE 2

ONTARIO APPAREL WASTE SURVEY

Number of Firms Participating: 93

Waste Material	Sold to Dealers (lbs)	To Dump (lbs)
Unspecified	19,800	104,025
Clippings Cotton	375,776	201,170
Clippings Cotton/Poly or Acrylic	273,253	596,312
Clippings Cotton/Nylon		7,903
Wool and Wool Blends	21,918	188,919
Rayon	30,600	62,488
Leather		58,924
M.M. Fibres	70,550	29,858
Nylon		42,172
Arnel/Nylon		12,675
Vinyl		12,912
	791,897	1,317,358
Cost to Dump		$75,377.00

Received from Waste Dealers $194,394.00

SUMMARY

	Cost to Dump	Amount to Dump (lbs)
Apparel Waste	$ 75,337.00	1,317,358
Textile Waste	194,110.00	8,364,049
	$269,487.00	9,681,407

The geographic breakdown of fibre and fabric wastes in Ontario in terms of volume and fibre type are shown in Figures 1 and 2.

Textile waste which is not being recycled in Ontario can be defined as being in two categories:

- waste of a marketable type, which is not now being recycled by the existing private enterprise system
- waste of a type for which there exists no commercial market

This appears to be a simple situation, but upon examination, it quickly becomes apparent that it is a very complex problem.

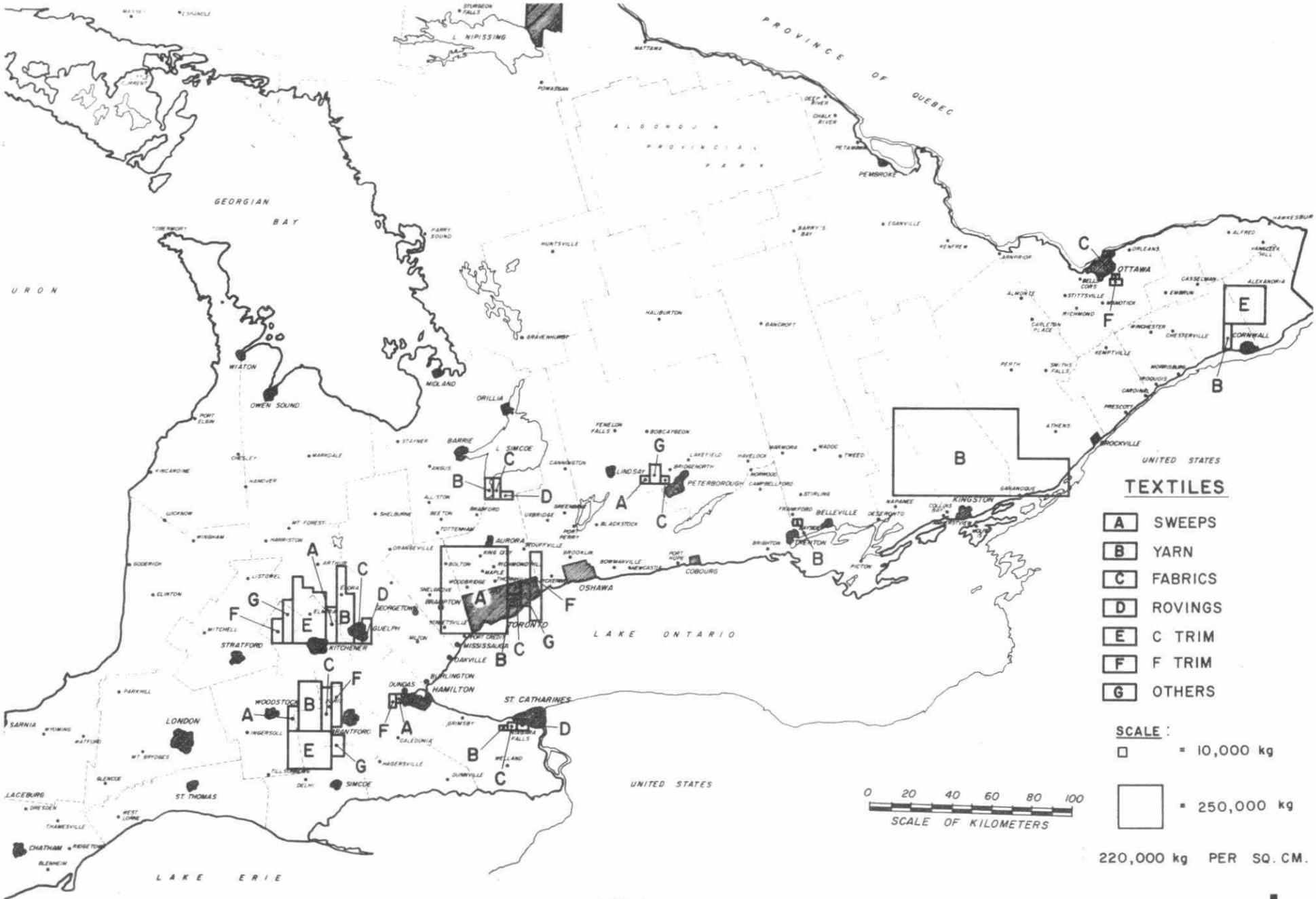

FIGURE 1

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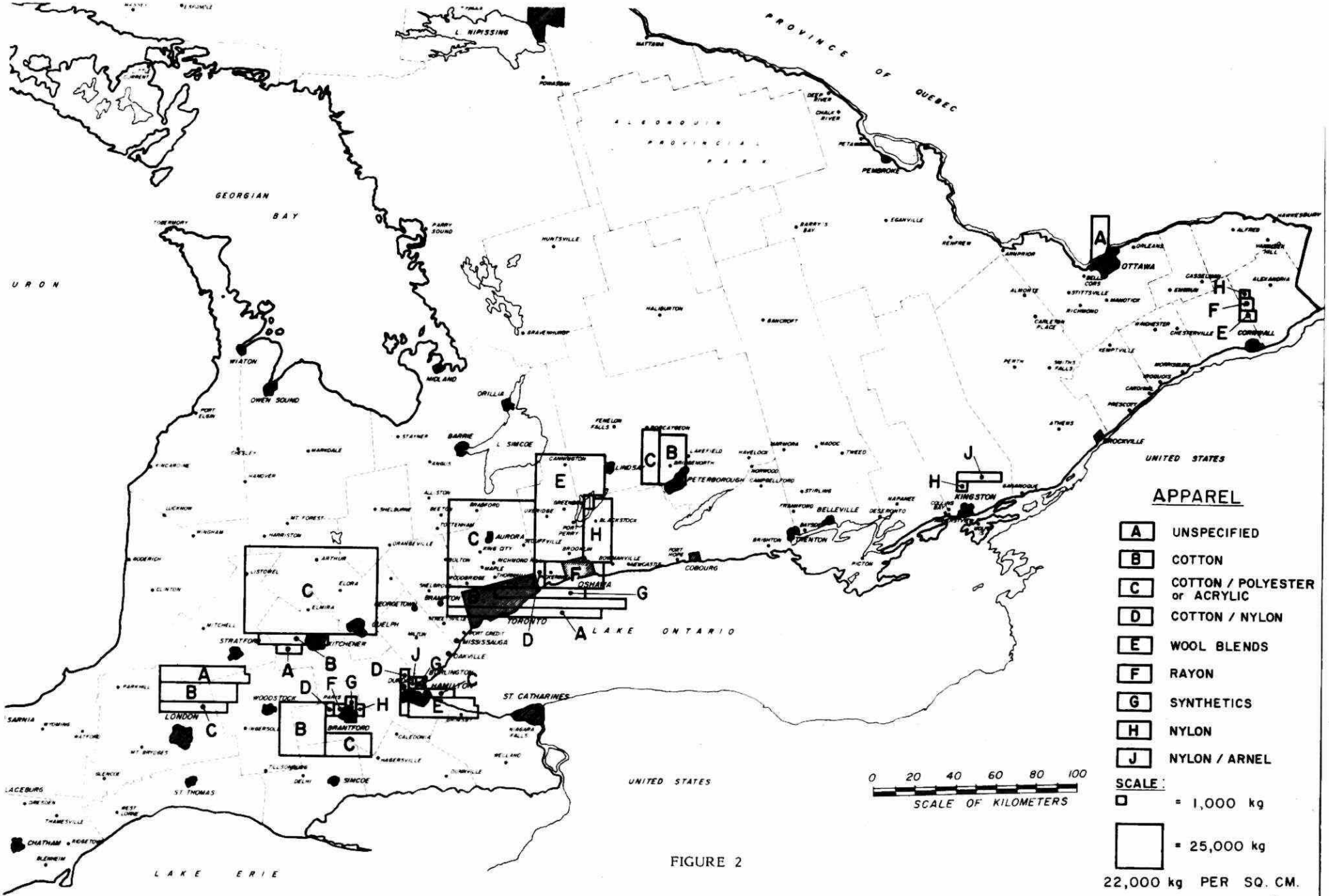
L. NIPISSING
PROVINCE OF QUEBEC
ALGONQUIN PROVINCIAL PARK
GEORGIAN BAY
HURON
PEMBROKE
OTTAWA
KINGSTON
BELLEVILLE
PETERBOROUGH
OSHAWA
TORONTO
BARRIE
ORILLIA
OWEN SOUND
WIARTON
MIDLAND
COBOURG
BROCKVILLE
CORNWALL
LONDON
BRANTFORD
HAMILTON
ST. CATHARINES
KITCHENER
GUELPH
STRATFORD
SIMCOE
ST. THOMAS
SARNIA
CHATHAM
LAKE ONTARIO
LAKE ERIE
UNITED STATES
UNITED STATES
0 20 40 60 80 100
SCALE OF KILOMETERS
APPAREL
A UNSPECIFIED
B COTTON
C COTTON / POLYESTER or ACRYLIC
D COTTON / NYLON
E WOOL BLENDS
F RAYON
G SYNTHETICS
H NYLON
J NYLON / ARNEL
SCALE :
= 1,000 kg
= 25,000 kg
22,000 kg PER SQ. CM.
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FIGURE 2

2.1 Marketable Waste

This is essentially an economic problem involving the following factors:

(a) Sorting. The cost of sorting waste has been escalated by increased skill required to sort complex fibre blends. Textile manufacturers are reluctant to set up their normal production to reduce the mixing of fibre or fabric types. Unless the trading equation is biased towards demand, waste dealers will only sort large units of volume. Therefore small units of waste accumulation remain unwanted.

(b) Storage. Accumulation of waste is often slow, and comparatively, space is uneconomically employed in the storage of waste.

(c) Transportation. Unless waste is compress baled, transport cost is very high, and a large number of textile companies cannot justify the investment of baling machinery versus the return on recovery and, as a result, are simply dumping. The matter of scale is particularly important in this regard.

One concludes that the main reason that marketable waste is being dumped is a matter of economics; it increasingly costs more to sort, store and transport than its value in the market. It is simply cheaper to pay a waste disposal company to cart it away to the local dump.

The solution is to change the cost/value relationship.

Changes that can be brought about on the cost side are:

(a) penalize dumping, by municipal dumping fee

(b) subsidize transportation

(c) subsidize installation of baling machinery to reduce transportation costs

(d) organize waste collection and sorting operations in areas where there are concentrations of small companies, producing collectively, a

large amount of waste, such as Toronto's Spadina Avenue garment district. This sytem would generate make-work programs in co-operation with U.I.C.

On the value side the following changes could be made:

(a) Government assistance in exploiting export markets

(b) amend existing labelling regulations to permit labelling of recycled new material as new filler for upholstery and quilting, now required to be labelled as used material

(c) initiate research into new uses of textile wastes

2.2 Non-Marketable Waste

These are wastes which are either complicated chemical and/or physical compositions, such as:

- carpet clippings, which are mechanically inseparable mixtures of textile yarns, foamed rubber or urethane, and polypropylene or jute fabric
- tire waste, mechanically inseparable mixtures of rubber and manmade fibre in yarn form

Or textile wastes of relatively simple composition, for which there is no existing market, such as:

- so-called "round fibre", i.e. fibre so short in length that it cannot be used for further textile use

As far as the composite wastes are concerned the answer lies either in the development of new methods of mechanical separation, and/or in the development of new methods of chemical and/or mechanical reduction, to produce new types of raw material, such as fuel, fillers and paving materials.

For the textile wastes of relatively simple composition the solution lies in either the development of new products, such as short fibre for flocking, or oil spill absorption, and/or development of processes to re-convert chemical fibre to original or modified polymer.

In examining the matter of disposal of textile wastes in Ontario, probably the most significant factor is that the present basic philosophy in waste recycling is the modification of the material so that it can be re-directed into the textile manufacturing cycle. In broad terms, the solution to the problem is two-fold:

(1) Through Government, to transfer to industry, as incentives, the benefits which accrue to society from recycling via the existing system.

(2) Developing new methods of recycling, waste conversion and new markets for textile wastes, through technological advancement.

The following sections of this report discuss in more specific terms current and potential approaches to the problem of textile waste utilization which may have application to the situation in Ontario.

Appended are details of interviews with selected producers and users of textile waste in Ontario.

3.0 ENERGY RECOVERY FROM TEXTILE WASTES

Textile materials have a heating value which on a per pound basis is approximately 75-80% of coal and about 50-60% of oil. Various heating values for different textile materials have been reported as being between 6,500 and 12,000 Btu/lb. With the increasing quantities of petroleum based man-made fibres, the average heating value of textile waste is increasing. For the purposes of this study we will consider an average value of 9,500 Btu/lb for all textile waste materials.

Obviously any material which has a heating value approaching that of coal has a potential value as a fuel. Our objective is to try to determine whether that potential value can be economically realized.

Utilizing textile waste as a fuel has several advantages over material reuse schemes. These are:

- Value can be readily realized in the producer's plant
- No separation of fibre type is necessary
- Other combustible wastes may also be utilized in this way
- Technology is available today to realize the heating value.

On the other hand there are several dissadvantages to this approach, including:

- Relatively low value attached to the fibre compared to some material reuse applications
- Relatively large quantities of waste in a single location are required to make the approach economic
- Does not maximize resource conservation
- Product energy is relatively low grade, viz. hot water or low pressure steam.

It is unlikely that textile waste would be an attractive enough fuel for a plant to be able to sell it as such. Thus, any utilization would have to be within the waste producer's plant. The amounts of waste

produced by individual textile plants in Ontario are in the majority of cases quite low. Tables 3 and 4 show a breakdown of numbers of companies by amount of waste produced (regardless of fibre type or physical form). Only 35% of the textile plants and 3% of the apparel manufacturers in Ontario produce more than 100,000 pounds per year of waste.

This waste production rate of 100,000 lbs per year is likely to be the minimum which could even be considered for potential fuel recovery. 100,000 lbs per year is about 12 lbs per hour on a year round basis. The smallest commercially available incinerators are designed for about 50 lbs per hour of waste material feed. It may be that, if the energy from the waste is to be utilized for plant heating, this requirement would only exist in the winter, so that wastes could be stored during the summer months to be fed to the incinerator/boiler in the winter time.

From the standpoint of system economics, the quantity of waste is critical. Potential saving by diverting waste material from the dump to a fuel use is made up of two components

- Savings by not having to dump the material
- Savings by replacing purchased fuels

According to the Ministry of Industry and Tourism's Textile Waste survey, the average cost to dump both textiles and apparel waste in Ontario is 2.8¢ per pound.

Assuming that the textile waste at 9,500 Btu per pound replaces a distillate fuel oil with a heating value of approximately 170,000 Btu/gallon which costs 44¢ per gallon, the fuel value of the textile waste is 2.5¢ per pound. The total potential saving is thus 5.3¢ per pound.

Examples of total potential savings for various levels of waste production are given in Table 5. In Table 6 specific plants identified by the Ministry of Industry and Tourism Waste Textile survey as generating more than 100,000 lbs per year of waste textiles are considered. Potential savings for each of these plants are calculated using the average Ontario cost for

dumping and also using the plant's own estimated cost for its dumping charges.

Given these levels of potential savings, consideration can be given to whether the potential can be realized economically. It is quite difficult to deduce this in general terms. In all but four or five of the largest plants listed in Table 6 the savings are quite small.

In order to achieve the potential savings, capital investment will be required in a waste burning facility and a boiler and distribution system for hot water or steam product. It may be possible to modify existing energy recovery systems to incorporate the waste burning facility, thereby minimizing new investment. Storage facilities may be required if, say, the waste is used only for plant heating during the winter time. In most instances, particularly for small installations, the waste incinerators are batch operated requiring a feed every few hours. This may require additional manpower, although it is most likely that this duty could be combined with other plant maintenance or operating duties without causing a very onerous additional work load.

A small waste incinerator purchased by Ontario Research recently was installed with a boiler, scrubber, stack and full instrumentation for $25,000. This unit is capable of burning 250 lbs of waste over a 5-hour period. This 50 lb per hour unit is about the smallest available commercially.

The consideration of whether installing such an energy recovery system would be economic would have to be done on a plant by plant basis. The rather crude economic discussion below is designed only to establish that, in plants producing larger quantities of textile wastes, the potential savings in using waste as a fuel warrant further detailed investigation.

The "present value" of a series of annual payments is used to determine the savings required per annum to make worthwhile an investment of $25,000.

If money is valued at 10% and it is assumed that the incinerator should be depreciated over a 10-year period, a series of 10 payments of $x would have a "present value" of $6.145x. Thus, for an investment of $25,000,

a series of 10 payments of $\$\frac{25,000}{6.145}$ would be required, i.e. $4,070 per year.

A plant producing 100,000 lbs per year of waste has been shown to have the potential for saving $5,300 per year by using that waste as a fuel. Paying $4,070 for capital charges would leave $1,200 per year for additional operating and maintenance charges which would most likely be a very marginal operation. It must be remembered, however, that this same incinerator could be used for plants producing up to 400,000 lbs per year of waste without increasing the capital charges. At this level of waste production, potential savings are $21,200 which would allow $17,100 to cover additional operating and maintenance costs, or to show a profit on the operation.

The above analysis assumes that the costs of dumping and price of fuel remains the same, over the 10-year period considered. This is, in fact, unlikely. It is probable that the costs of fuel and waste disposal will increase substantially in the years ahead. This will substantially increase the "savings" realized by converting this waste problem to an energy source.

For plants generating large amounts of waste per year, a more sophisticated incineration system incorporating automatic feeding of the unit might be considered. A system of this type has been recently installed in an apartment complex to recover energy from mixed garbage. The installed cost of this unit is estimated to be $130,000 and it is capable of burning 250 lbs per hour, or approximately 2 million pounds per year. The potential savings for a textile plant producing 2 million pounds per year of waste material and using that waste as a fuel is $106,000.

Annual payments required to give a present value of $130,000 over a 10-year period with money valued at 10% would be $21,200. With saving potential of $106,000, this prospect is economically extremely attractive.

A supplementary benefit of this approach to the textile waste disposal problem is that it would allow other combustible waste material to be utilized at the same time. This may increase the quantities of waste in plants with smaller textile waste generation problems, to the extent that energy recovery becomes economically attractive.

For plants whose only use for energy is for plant heating in the winter time, this may be accommodated by providing storage for the waste material during the summer months. For large waste generators this may give rise to space problems. Even for plants producing 100,000 lbs/year, storing 50,000 lbs requires a fairly large area. Assuming a bulk density of ∿ 15 lbs/cubic foot, this would represent a 3,333 cubic foot pile which is about 20 feet x 20 feet ·10 feet high. The cost of 400 square feet of storage space would have to be subtracted from the potential savings.

It is recognized that the foregoing analysis is not very definitive. In order to make it more definitive, an individual textile plant situation would have to be considered. Some things existing in an individual plant may make the use of waste as a fuel more attractive, while others may make it less so. For example, in some plants it may be possible to modify existing boilers to utilize heat generated by a waste incinerator, thus halving the required capital investment by eliminating the need for a new boiler.

It is concluded that the use of textile wastes as fuels in the plants in which they are generated is likely to be economically attractive for the four or five largest waste producers in Ontario listed in Table 6. These plants generate 6.9 million pounds per year of textile wastes which represents 71% of the total textile waste produced in the province. A further 8 plants also listed in Table 6 may find it economically worthwhile to consider recovering energy from the wastes they produce. Between them these 8 plants produce 1.302 million pounds per year which represents a further 13.5% of the total waste textiles problem.

As was stated earlier, this use for textile waste is technically attractive as no processing or separation of wastes by fibre type or physical format is required. Because of the low value per pound for this use, it is recommended that it be used as a "fall back" position if no material reuse approach proves to be feasible.

One final consideration of textile waste as a fuel is what air pollution problems are likely to arise from such a practice. Modern incinerator design with multiple chambers and long residence time takes care

of problems such as carbon monoxide or carbon particulate production by complete oxidation. Particulate emissions of five inorganic coatings or dust and dirt adhering to the textile waste are also minimized by the incinerator design. Other emissions have to be considered by individual material type. Elements which may have the potential for creating air pollution problems from textile waste are the halogens (chlorine and bromine) and sulphur. Sulphur is found only in some natural fibres such as wool. Chlorine is a constituent of P.V.C. and would give rise to both air pollution and severe boiler corrosion problems if this particular material were burned. P.V.C. constitutes a very small fraction of the textile waste problem in Ontario (< 0.15%) and this material should be eliminated from any energy recovery scheme.

Halogenated compounds are also used as fire retardants on some materials. These are applied as a fairly small percentage of the total fabric weight, and should not, therefore, give rise to any excessive emissions of hydrogen, chloride or bromide. Prior to an individual plant installing a waste burning facility, consideration should be given to the types of fabrics and their finishes. It is felt, however, that there will be very few instances when air pollution will be a major negative factor.

TABLE 3 - Textile Waste by Extent of Company's Problem

Waste Generated	Region													Total (no. of Establishments)
	1	2	3	4	5	6	7	8	9	10	11	12	13	
3-4 million lbs/annum	-	-	-	-	-	-	1	-	-	-	-	-	-	1
2-3 million lbs/annum	-	-	-	-	-	-	-	-	-	-	-	-	-	0
1-2 million lbs/annum	1	-	-	-	-	-	-	-	-	-	-	-	-	1
0.5-1 million lbs/annum	-	-	-	-	-	-	-	1	-	-	1	-	-	2
200-500 thousand lbs/annum	1	-	1	-	-	-	-	-	-	-	-	-	-	2
100-200 thousand lbs/annum	-	-	3	-	-	-	-	-	-	-	1	1	-	5
75-100 thousand lbs/annum	-	-	1	-	-	-	-	-	-	-	-	-	-	1
50-75 thousand lbs/annum	-	-	-	-	-	-	-	-	-	-	-	-	-	0
40-50 thousand lbs/annum	-	-	-	-	1	-	-	-	-	-	1	-	1	3
30-40 thousand lbs/annum	-	-	-	-	-	-	-	-	1	-	-	-	-	1
20-30 thousand lbs/annum	2	1	2	-	-	-	-	-	-	-	-	-	-	5
10-20 thousand lbs/annum	1	-	1	1	1	-	-	-	-	-	-	-	-	4
5-10 thousand lbs/annum	4	-	-	-	-	-	-	-	-	-	-	-	-	4
< 5 thousand lbs/annum	2	-	-	-	-	-	-	-	-	-	-	-	-	2
TOTAL	11	1	8	1	2	0	1	1	1	0	3	1	1	31

TABLE 4 - Apparel Waste by Extent of Company's Problem

Waste Generated	Region													Total (no. of Establishments)
	1	2	3	4	5	6	7	8	9	10	11	12	13	
100-200 thousand lbs/year	1	-	1	-	-	-	-	-	-	-	-	-	-	2
75-100 thousand lbs/year	2	-	1	-	-	-	-	-	-	-	-	-	-	3
50-75 thousand lbs/year	-	-	-	-	-	-	-	-	-	-	1	-	1	2
40-50 thousand lbs/year	-	1	-	-	-	1	-	-	-	-	1	-	-	3
30-40 thousand lbs/year	1	-	1	-	-	-	-	-	-	-	-	-	-	2
20-30 thousand lbs/year	3	-	-	-	-	1	-	-	1	-	-	-	-	5
10-20 thousand lbs/year	7	-	1	-	-	1	1	-	-	-	1	-	-	11
5-10 thousand lbs/year	8	-	-	2	-	1	-	1	-	-	1	-	-	13
2-5 thousand lbs/year	12	1	-	1	-	-	-	-	-	-	-	-	-	14
1-2 thousand lbs/year	5	-	-	-	-	-	-	1	-	1	-	-	-	7
< 1 thousand lbs/year	-	-	-	-	-	-	-	-	-	-	-	-	-	0
TOTAL	39	2	4	3	0	4	1	2	1	1	4	0	1	62

TABLE 5

Waste Produced lbs per year	Potential Savings by using waste as a fuel $/year
100,000	5,300
200,000	10,600
500,000	26,500
1,000,000	53,000
2,000,000	106,000
3,000,000	159,000

TABLE 6

Potential Savings for Textile Firms Using Waste as a Fuel

Firms as per Textile Waste Survey	Total Waste Generation lbs/year	Potential Savings by Use as a Fuel	
		(Based on Average Dumping Fee) $/year	(Based on Company's Estimated Dumping Fee) $/year
7T3	3,500,000	185,500	137,500
1T1	1,500,000	79,500	62,500
11T4	882,700	46,783	40,667
8T1	655,000	34,715	26,375
3T7	375,000	19,875	17,375
1T14	262,500	13,912	26,562
11T3	200,000	10,600	9,500
3A6	190,718	10,108	7,215
3T4	149,500	7,923	8,937
3T10	137,000	7,261	10,425
3T8	133,100	7,054	3,928
12T1	123,500	6,245	4,587
1A29	106,250	5,631	5,156

4.0 INDUSTRIAL WASTE MATERIALS EXCHANGES

The concept of an industrial waste materials exchange is a vehicle by which the availability of waste material or by-products is made known to as many potential users as possible. In Europe and in North America several of these Exchanges have been established since 1973. They are directed towards trying to find new uses for industrial materials, now being discarded, particularly those that are environmentally hazardous. Textile waste obviously does not fall into the category of a "hazardous" waste. It is, however, costing producers a reasonable amount of money to dispose of it each year.

Making as many people, in as many different industries as possible, aware of the existence of these waste streams maximizes the chance of someone thinking of a good use for a very low priced raw material.

Publicizing the fibre type and physical format of the wastes available may spark an idea for utilizing this material in a company totally remote from the textile industry. If the exchange is working properly every person who receives the list of available wastes put out by the exchange is "researching" possible uses for each waste on the list. All of these "researchers" have different backgrounds and interests, which significantly increase the chances of finding novel uses for materials presently considered to be useless.

In a recent study[1] ORF examined the operation of 18 Waste Materials Exchanges in Europe and North America. One of the Exchanges studied was the Ontario Ministry of Industry and Tourism's "Profits from Waste" section in their Manufacturing and Diversification Opportunities Bulletin. One page of this bulletin, which was issued in January, 1976, is reproduced as Figure 3, showing the relevant textiles sections. As can be seen there is a "Wanted" as well as an "Available" list, so that people who are looking for waste materials can make their needs known. This bulletin is distributed to about 6,000 industrialists in Ontario, and on the average M.I.T. received 2 enquiries for every item listed. A code number is

assigned to each listing to retain anonymity for the lister. This is perhaps unimportant for textile wastes, but for chemical and other more hazardous wastes confidentiality is felt to be a worthwhile feature of the waste exchange.

Many of the exchanges in Europe and in the United States operate along very similar lines. Because the M.I.T. exchange serves only Ontario and also because it concentrates more on the secondary rather than the primary manufacturing sector, ORF recommended at the conclusion of their study that a Canada-wide exchange, aimed primarily at primary industries producing hazardous waste materials be established. It is hoped that this exchange will issue its first bulletin in the Fall of this year. While the major thrust of this exchange will be to chemicals and sludges, it will have textile, paper and plastics sections.

It is recommended that textile manufacturers utilize the existing M.I.T. Waste Exchange and the new Canadian Waste Materials Exchange, when it is established, to publicize the availability of waste material from their operations.

FIGURE 3 - Ministry of Industry and Tourism

Industrial Waste Exchange: Textiles Section

PROFITS FROM WASTE

TEXTILE, FABRIC, LEATHER & RUBBER PRODUCTS WANTED

- All fabrics, household needs, manufactured garments, (ends of runs, clearings, odd lots) any size, any quantity. (Port Dover). — PFW # 1
- Textile fibers in quantities of 25,000 lbs. or 5,000 lbs. per month or more. (Lachute, Quebec). — PFW # 2
- Red cotton, Hi Viz Nylon, 20" wide, unlimited quantity. (Rexdale) — PFW # 3
- Cotton rags, pieces, several 100 lbs. quantities required. (Sarnia). — PFW # 4

TEXTILE, FABRIC, LEATHER & RUBBER PRODUCTS AVAILABLE

- Foam rubber, 1/2" x 2-1/2" x 56" size, 2,000 per year.
  Foam rubber, 1" x 9" x 20', 500 per year. (Woodstock) — PFW # 5
- Leather slugs, 3" to 5" approx. 14 dia. — PFW # 6
- Various sizes: carpet waste, 60,000 lbs. yarn waste, 25,000 lbs., fibre waste, 25,000 lbs. (Bramalea) — PFW # 7
- Fabric cuttings (all cotton and polyester & cotton) small pieces and narrow strips, approx. 2,000 lbs. per month. (London). — PFW # 8
- Shearing waste from high pile orlon, polyester, etc. 1/4" to 5/8" random mixed, 2,000 lbs. daily (Lindsay). — PFW # 9
- Felt, various sizes, 50 lbs. per week.
  Corks, various sizes, 100 lbs. per week. (Brantford) — PFW # 10
- Textile clippings (large quantities) from manufacturer of men's & boys' jeans and slacks. (Toronto) — PFW # 11
- Woven cloths, 6" x 6" and 7" x 148", 500 lbs. per month.
  Needled felts, 6" x 6" and 7" x 148" 500 lbs. per month.
  (St. Catharines) — PFW # 12
- Cow hide flashings, 1250 tons per year and chrome shavings, 3000 tons per year. (Oshawa) — PFW # 13
- Wool cuttings and ends, synthetic ends and cuttings, small supply of fake fur ends. Available by the pound. (Toronto) — PFW # 14
- Orlon pile fabric, 14" x 11" & smaller, unlimited supply. various colours. (Oakville) — PFW # 15
- Cotton waste, 8 oz. canton, 500 lbs. per week.
  Leather splits, cuttings (high oil content) 2-3,000 lbs. per week.
  Leather splitting & shaving waste, 15,000 lbs. per week. (Acton) — PFW # 16
- Cloth cuttings (polyester & cotton blends)
  (Kitchener). — PFW # 17
- Polyester double knits, cuttings, from manufacturer of ladies' slacks/sports wear, etc. One ton per week. (Guelph). — PFW # 18
- Upholstery felt, small pieces, upholstery fabric cuttings, small pieces, quantity generated steadily. (Whitby). — PFW # 19

5.0 TEXTILES FROM WASTE TEXTILES

Energy conservation and environmental preservation concerns have focussed attention on the problems of recycling wastes in all sectors of industry. However, the problem of waste recycling is distinct from energy conservation in that waste usually comprises materials in a usable condition, provided that suitable separation and sorting is possible - unlike sources of energy, the materials comprising waste are not being destroyed. Waste recovery is already a considerable industry; according to a recent Battelle Memorial Institute report, textile recycling was an $84 million industry in the U.S. in 1969, and it showed considerable potential for growth.

Textile waste, whether from fibre manufacturers, mills, weavers or consumers, will follow one of the following routes:

(1) Disposal - that is by dumping, landfill, burning, etc.

(2) Energy production - i.e. use as a fuel

(3) Recycling (non textile) - the waste may be processed into a non textile product, e.g. paper, extrusion mouldings, etc.

(4) Recycling (textile) - the waste may be reprocessed for textile products, either the same or different to the source of the waste.

#1 of these four is, of course, the one that it is hoped can be avoided as much as possible. (2) and (3) may both be desirable in particular cases; neither is likely to realize the 'intrinsic value' of the material, i.e. the market value of the original textile. (2) may be a profitable route where large quantities of waste are available in a particular area, or where transport of a large bulk of waste to a particular site is feasible. (3) is likely to be an expanding field for textile waste utilization where circumstances do not permit route (4). This latter route is the only one where it may be possible to realize a significant portion of the inherent value of the waste. For a number of reasons, most notable of which is the increasing use of synthetic blends, route (4) may be impossible or uneconomic in many instances. It is already used routinely in certain areas of the textile industry, such as fibre production, where the waste is generally pure and is easily recycled using equipment already operated for the purposes of normal fibre production.

The possibility for recycling of waste for textile purposes is governed by a number of factors, some of which have become of increasing importance in recent years. When the material is pure and undyed, recycling is not usually a problem, and may be achieved by various routes dependent on the nature of the waste, e.g. -

(1) Fibre waste - reprocessing using conventional yarn manufacturing equipment

(2) Fabric waste - garnetting into fibre form and processing as (1)

(3) Cellulosic waste (unsuitable for yarn manufacture) - sale to paper making industry.

When the waste is not pure or is dyed, recycling economically is more difficult. The increasing use of blended materials has had serious consequences for the secondary textile industry since separation of the blend is generally not feasible. Dyed wastes, if they are to be reused for textile applications, must usually be separated into colour matching groups; this is labour intensive and therefore expensive. These problems combine to make textile reuse not viable for a large sector of the secondary textile industry. While it may be possible to reduce the problems in some cases, there will no doubt be an increasing interest in reprocessing waste textiles into non textile products, where the colour and blend problems are less important.

The fibre blend problem is discussed in more detail in the following section, followed by sections on the problems (including blend problems) faced by the wool and cotton reprocessing industries at the present time. A promising process for recycling of polyester/cotton blends is outlined in the cotton reprocessing section.

5.1 Fibre Blends

Since the Second World War the use of textile materials containing more than one kind of fibre type has dramatically increased; especially important, and still rapidly growing, is the use of polyester in blends with cotton or wool. The following table, taken from Chemical and Engineering News (April 20, 1970) shows the growth since 1960:

DOMESTIC PRODUCTION OF MAN MADE FIBRE
1960 - 1980 (MILLION POUNDS) (U.S.)

	Rayon	Acetate	Nylon	Polyester	Acrylic	Olefin	Glass
1960	740	290	375	100	150	13	175
1965	1080	445	935	400	370	65	280
1970	1215	580	1565	1365	600	280	525
(est)1975	1450	735	2000	1770	845	450	725
(est)1980	1700	910	2600	2800	1100	790	900

Much of this MMF production will be consumed by fibre blends (e.g. polyester/cotton, wool/acrylic, etc.). Little recycling of these blends is being performed at the moment, although technology to do so appears in some cases to be practicable.

The bulk of the recycling problem with blends will involve material already made up into fabric form. The table below refers to the average percentages of waste produced by various sectors of the textile industry in the U.K.

Process	Staple Fibres (includes natural)	C.F. Fibres
Prespinning	8%	5%
Spinning) Weaving) Knitting) Dyeing) Finishing)	1.5%	1.5%
Making Up	Woven 12% Knitted 20%	Woven 12% Knitted 20%

This table shows that it is in the making up area of the industry that high wastage occurs in terms of percentage of material processed. The pre-spinning stage involves pure material that is relatively easy to recycle; the making up sector is involving increasing amounts of blended fabrics. In the U.K. in 1973, pre-spinning wastes of 90 million lbs. were produced, most of which was recycled; garment maker wastes were 57 million lbs. All other processing areas totalled 10 million lbs. The amount of waste produced in garment making in the U.S. in 1970 was about 400 million lbs., of which about 60% was recovered.

The problems in recycling these clippings depend on the fibre content. The following table (U.K. Clothing Institute Journal, 1975) shows the potential recycleability of fabric clippings in the U.K. in 1973:

Fibre Content	Recycling Value		End Uses
	White	Dyed	
Wool/Worsted	High	High	Yarn, nonwovens, felts
Wool/Worsted Blends	High	High	Yarn, nonwovens, felts
100% Cotton, Rayon	High	Moderate	Yarn, surgical waddings
100% Synthetics			
Knitted	High	Moderate	Fillings, Waddings
Woven	Moderate	None	Fillings, Waddings
Synthetic Blends			
Knitted	Low/Moderate	None	Possibly low quality fillings
Woven	Low	None	Possibly low quality fillings

The low value of synthetic fabric waste is usually a result of the high strength of these materials; dyed fabrics are of even less value. Knitted materials are somewhat easier to process via garnetting machinery.

Most waste in the garment industry is produced at the 'cut and sew stage'. While it may be possible in some cases to reduce waste to 5%, typical figures are 12-35% for woven fabrics and 20-25% for knits.

The considerable variety of different blends, together with the various colours and finishes involved, may in general suggest that non-textile outlets such as injection mouldings, timber substitutes, etc. may be more promising as outlets for recycling clippings. However, certain areas of the apparel industry, most notably the polyester/cotton shirting industry, appear to offer practicable possibilities for recycling of waste; it is important to note that recycling textiles for textile end use is likely to be more cost-effective than non-textile applications.

The economic importance of new methods for separation of pure natural fibres from wastes containing blends will remain despite the fact that the greater volume fraction of fibres used in textiles in increasingly synthetic. This is illustrated by the following table, showing consumption of cotton and man-made fibres (MMF) in the U.S. (source Battelle report 1972).

BILLION POUNDS, CONSUMPTION

Year	Cotton	MMF
1960	4.2	1.9
1970	3.8	5.5
1971	4.0	6.5
1972	3.8	7.6
1973 (predicted)	3.7	8.8

This indicates that although MMF consumption is rapidly increasing (primarily nylon, polyester and acrylic) cotton consumption is remaining at a fairly constant level; the same is true for wool consumption. However, it can be expected that the present trend for increasing use of blends of cotton and wool with synthetics will continue, thus aggravating the problem of waste fibre recovery and furthering the need for suitable reclamation techniques. In the U.S. at the present time, approximately 10 billion pounds of blended waste is produced per annum (including about 4 billion pounds of blended material in used clothing). To realize the maximum monetary value for this material it is desirable, wherever possible, to use the route (4) (recycling for textile use) discussed earlier. A possible textile reuse

for blended-fibre used clothing is resale to underdeveloped countries unable to supply their own clothing needs; this is a promising market but it is at the moment hampered by tariff systems that are designed (not always from real necessity) to protect a growing domestic textile industry.

5.2 The Cotton Reprocessing Industry

In the cotton recycling industry the diminishing volume of pure cotton waste is creating difficulties in the traditional waste cotton markets. The major markets for such waste are vulcanized fibre, rag paper and wiping cloths. The vulcanized fibre and rag paper industries require cotton waste of high purity, usually less than 2%. Waste of this quality is becoming scarce as the proliferation of polyester/cotton blends continues.

One of the three major U.S. vulcanized paper industries has already changed from cotton waste to an alternative source (cotton linters and wood pulp) for their cellulosic material requirements. The other two producers are considering similar moves. There is therefore good reason to examine the possibility of recycling polyester/cotton blends to produce a pure cellulosic component suitable for this end use.

Several techniques for separation of polyester/cotton have been used in the past, for example:

(1) Carbonization of the cotton
(2) Acid solvation of the cotton
(3) Ethylene glycol solvation of the polyester

These techniques are not efficient in terms of recovery of usable components. Recently suggested procedures offer the possibility of recovery of both the cellulosic and polyester components in marketable textile forms. Two of these are discussed in detail here; they are the TRI (Textile Research Institute, New Jersey) Acid Process and the TRI Acetylation Process. Both of these show promise of industrial feasibility.

5.2.1 TRI Acid Process

Waste polyester cotton is treated with dilute mineral acid. This achieves the desired controlled hydrolysis of the cotton as well as removal of resins and other finishes. Typical conditions are sulfuric acid, 5-10%, at 80-100C for 15-60 minutes. The conditions will dictate the chemical state of the cellulosic product.

The acid treated waste is now subjected to wet mechanical action during agitated aqueous washing. The weakened cotton fibres are broken into short lengths (fibrets) and form an aqueous suspension. The physical nature of the fibrets is controllable by the degree of turbulence, temperature and duration of this step; experimentation suggests that a typical washing operation is suitable. The polyester component residue is now removed and washed. The resultant fabric polyester is clean and sheer and may be easily garnetted into staple fibre. The dispersion of cellulosic fibrets may be concentrated by evaporation or spray/freeze drying to pure cellulosic fibrets. These should be easily marketable in applications where pure cellulosic material is required, especially the paper industry.

5.2.2 TRI Acetylation Process

The waste polyester cotton is pretreated with dilute acid to remove resin and other finishes. A standard acetylation reaction procedure is now followed such as this one:

(1) Activation treatment using glacial acetic acid
(2) Agitate for 5 minutes in glacial acetic acid containing 0.5% sulphuric acid
(3) Add acetic anhydride, agitate for 2 hours

Actual conditions will vary depending on the exact nature of the waste.

When the cellulose acetate formed becomes solvated in the liquor, the polyester fabric can be removed and washed with glacial acetic acid. Water or dilute acetic is added to the residual liquor to precipitate the cellulose acid, which is recovered by evaporation or filtration. The flakes may be reprocessed into films or fibres by well established commercial methods.

These procedures give yields of about 90% or better for the polyester and cellulosic components.

5.3 The Wool Reprocessing Industry

The wool reprocessing industry, once considerable in the U.S. and Britain, has declined considerably in recent years due to a number of circumstances. Primarily these are wool labelling regulations and contamination of wool with synthetics. According to the 1972 Battelle Report, the U.S. wool reprocessing industry has declined to the point where it is currently an insignificant factor in the total U.S. textile industry. In the U.K., the Atkins report showed that 25.4 million kg of wool rags were used in 1967, a decline of 37% in 19 years.

Wool labelling regulations in Canada, the U.S. and Britain stipulate that articles must indicate when reprocessed wool is used in manufacturing the articles. This leads to a significantly greater appeal to consumers for 'all wool' or 'virgin wool' articles when compared to articles marked 'contains reprocessed wool'. In general there is no basis for such preference in terms of quality or cleanliness; in fact it is difficult or impossible to distinguish good reprocessed wool from virgin wool. This latter point is shown by the fact that large volumes of wool articles from foreign countries are imported into the U.S. (especially from Italy) that contain reprocessed fibre, yet are marked 'pure wool'; it is not possible for it to be proved that reprocessed material is present and hence to demand relabelling. This makes it difficult for the domestic reprocessed wool industry to compete, since they must use the denigrating label 'reprocessed', and also affects the domestic pure wool industry since, unlike the foreign exporters, they cannot 'dilute' their products fibre content with cheap reprocessed wool.

The reprocessing industry can be divided into three groups:

(1) Soft rags - mainly knitted or open weave materials that can be easily pulled. These materials can be reprocessed into good quality reprocessed fibre that may be used in combination with virgin wool fibre. This part of the industry is the 'shoddy' industry.

(2) Hard rags - mainly tightly woven or milled fabrics. A lower quality of fibre is produced; this is the 'mungo' part of the reprocessed wool industry.

(3) Other wastes - wool rags that cannot be processed in (1) or (2). Over 90% of 'hard rags' must be disposed of in this category. Possible outlets are in linoleum and roofing felt manufacture.

Categories (1) and (2) have been severely hampered in recent years by the presence of synthetic fibres, usually acrylic or polyester. Amounts as small as 0.4% can cause serious problems in dyeing, as wool dyes are non-substantive on polyester and most acrylic fibres. Suitable dye formulations for mixtures of wool and synthetics, while presently feasible, are non-economic for the reprocessing industry.

Possible routes for alleviation of this problem include the following:

(1) Electrostatic separation. The blend is pulled into fibre form and electrostatic voltages used to separate the components as they are transported between charged plates using an air stream. While the feasibility of such a process has been shown, it appears unlikely that a pure enough (better than 99.5%) product could be reclaimed.

(2) Work in Japan (Toyobo) has produced polyester fibre that can be dyed in a one-dyebath process with wool using acid dyestuffs. If such fibres came into general use the problem of successfully dyeing reprocessed wools contaminated with synthetics would be largely removed.

(3) Solvent removal may be possible for synthetic contaminants in wool. Possible solvents for typical synthetics are as follows:

1. Acrylic - Dimethylformamide
2. Cellulosics - acid solvation
3. Polyester - ethylene glycol

While technically feasible, the main problem with such processes would be staying within the economic limitations of the wool reprocessing industry.

5.4 Sources of Information

CZECHOSLOVAKIA

1. Recycling of Secondary Raw Materials in Czechoslovakia,
KADLEC J.
Textiltechnik 12/1975 Vol. 25 #12 p. 747-749
In German

ENGLAND

1. A review of some problems in shoddy and mungo manufacture
WIRA* Report #42, January 1969

2. Electrostatic Separation of Wool and Man Made Fibres
WIRA* Report #72, October 1969

3. Reclamation of textile wastes
WIRA* Report #130, January 1971

4. Recycling in the Garment Industry, LUND G.
Clothing Institute Journal 2/1975 Vol. 23 pt. 2 p.99-107

5. Short Artificial Fibres (recovery of polyester from polyester/cotton blends),
DEACON, R.F.
Patent BP 1407617 18/09/72

* Wool Industries Research Association

FRANCE

1. Automatic Waste Removal in cotton spinning,
BINDER, R.
Ind. Textile 6/1975 Nr.1046 p. 323-328
In French

2. Waste Recovery in Spinning
Ind. Textile 8/1976 #1058 p. 436
In French

GERMANY

1. Fabrication of Non Wovens out of Textile Secondary Material in GDR,
HOYER W., BOETTCHER P.
Technishe Textilien 3/1976 Vol. 19 #3 p. 63-65
In German

GERMANY (Cont'd)

2. Necessity and State of Processing Textile Secondary Raw Materials,
RIEGEL D., POHL G.
Textiltechnik 10/1975 Vol. 25 #10 p. 618-623
In German

3. New Recycling Methods for Carpet Waste
Chemiefarsen 12/1976 Vol. 26 #12 p. 1103-1104
In German

4. Recycling of Textile Waste
Textil Praxis 11/1976 Vol. 31 #11 p. 1358
In German

5. Recycling of Waste from the Carpet, Woven and Plastics Industries
Melliand Textilbreichte 11/1976 Vol. 57 #11 p. 945, 946
In German

6. Recycling Products in Man Made Fibre Industry,
MICHELS, C.H.
Textiltechnik 6/1976 Vol. 26 #6 p. 343-346
In German

7. Removal of Floor Coverings after use,
WERRES B. and LEHNEN A.
Chemiefarsen 01/1975 Vol. 25 #1 p. 50-54
In German

ITALY

1. Waste Treatment in the Cellulose and Paper Industry,
BORRUSO D.
Textilia 7/1974 #7 p. 11-16 In Italian

NETHERLANDS

1. Market Analysis of the possibilities for the application of textile wastes
Report # 542303-01, Fibre Research Institute TNO
P.O. Box 110
Delft, Holland (1976)

2. Reclamation of Waste Polypropylene Fibre,
BADRIAN W., BADCON A.
Documentary Study S.1. 10/1975 p. 1-7

ROMANIA

1. By-Products Recovery in Flax and Hemp spinning,
AANEI C.
Ind. Textile - 01/1974 Vol. 25 #1 p. 41
In Romanian

SWITZERLAND

1. Fibre Recycling
Int. Text. Bull. Spinnerei 9/1975 #3 p. 330-331
In German

2. Fibre Waste Recovery
Int. Text. Bull. Spinnerei 10/1976 #3 p. 261
In German

3. High Production Rotary Cutting Machine
Int. Text. Bull. Spinnerei 10/1976 #3 p. 261-262
In German

4. Processing of Waste Fibre by Means of Rotor Spinning,
DOUGLAS K.
Book N. 30/S.I. 1976, 9 pages (Textile Trade Press)

UNITED STATES

1. Conversion of Nonwoven Fabrics into Staple Fibres,
PLATT L.
Patent USP 3941530 31/05/74

2. Cost Reduction (Waste Reduction and Efficiency Improvement)
Textile World 6/1975 Vol. 125 part 6 p. 51-76

3. Fast Way to Measure Trash in cotton and waste
Textile World 113(6) 64-65 June 1965

4. Fibre Identification in reclaimed textiles,
GEE, N.C.
Materials Reclamation Weekly 115(19) 195, 197-201 Nov. 1969

5. Man Made Fibre waste production
Textile Organon 37(6) P. 97, 104, 120 June 1968

6. Method of Recovering Constituents from Polyester and cellulosic textile waste,
GRUNTFEST I., TURNER R.
Patent USP 3937671 18/11/74

UNITED STATES (Cont'd)

7. Processing of Polyester Fibres wastes,
SPANIK K.
Item. Vlak 1975 Vol. 15 pt. 1 p. 11-12

8. Seven steps to cutting waste costs,
WILSON F.C., FOSTER C.W.
Textile World 116(2) p. 72-75 Feb. 1966

9. Shaped Articles from reconstituted Polyester
Patent USP 3804811 12/04/72

10. Study to Identify Opportunities for Increased Solid Waste Utilisation
Battelle Memorial Institute, Ohio June 1972

11. The Reclamation of waste polypropylene fibre,
BADRIAN, W.H.J.
Carpet and Rug Industry March 1977 p. 18

12. The Recycling of Textile Waste
Textile Research Institute Summary Report, Progress Report #3, Feb. 1974- July 1974

13. The textile and apparel waste industry in America,
FRANKEL, RICHARD
Apparel Research Journal Vol. IV No. III Dec. 1976, 107-109

14. Treatment of Textile Waste formed of polyester and cellulosic fibres,
GRUNTFEST I., TURNER R.
Patent USP 03937675 18/11/74

15. Waste at Roving - How much is too much?,
WILSON, F.C.
Textile World 114(9) p. 78-79 Sept. 1964

16. Waste Cellulose Possible Glucose Source
Chemical Engineering News 5/1974 #21 p.20

17. Waste Control Today - why you need it; how it works; how it pays off in three mills,
ASHMORE, W.G.
Textile World 114(4) 44-54 April 1964

18. Waste Recovery: big business in the '70s
Chemical and Engineering News 48(9) 14-5, March 1970

19. Waste Recovery of Thermoplastic Continuous Filamentary Material
EASTMAN KODAK
Patent USP 3795468 05/09/72

NOTES

Unless otherwise stated, papers are in English.

The dates given beside patents refer to dates of submission and not of patent number issue dates.

6.0 NON-TEXTILES FROM TEXTILE WASTES

6.1 Summary and Conclusions

The literature on the recovery and separation of organic waste fibres, and the utilization of organic fibres in composite materials is reviewed. In addition, a number of original ideas for the utilization of waste fibres are presented. Judgements are made on the appropriateness of many of the proposed applications for waste textile fibres.

Indications are that the separation of waste textile fibres into polymer types at the present time is not economically feasible. It is also doubtful whether separation into natural and synthetic fibres is feasible at this time. It is therefore concluded that the choice of markets for waste textile fibres is dependent upon the future development of effective and inexpensive separation processes, the ability to separate the textile wastes at the source, and the availability of markets for mixed textile fibres.

Considering applications for the waste fibres, one of the best seems to be for mixed fibres (natural and synthetic) in vinyl floor tile. There are also possibilities that chopped fabrics could be used in a new type of rigid, thermosetting insulating board. Another possibility is the utilization of pulled or shredded fabric in a low density sound or thermal insulating board, or in higher density structures similar to cellulose fibreboard. There are a number of possibilities for fabricated products in the form of sheets, slabs and moulded materials. Yet another possible use is as reinforcement in cement to improve impact resistance and prevent separation in the case of cracking.

It is believed that the above uses would provide the largest markets at the lowest processing cost.

6.2 Results of Survey

6.2.1 Fibre Recovery and Separation

Literature and patents exist on methods of recovering reusable fibres from woven and knitted fabrics, and from waste fibre such as entangled

filaments and knots. A German patent[1] includes a process for cutting woven fabrics at regular intervals followed by feeding to a drum with projections which catch up the yarns and remove them from the strips. A patent held by Du Pont of Canada[2] is for the production of discontinuous fibres from synthetic polymer filaments by means of a cylinder with needles mounted around the periphery, which rotates at high speed. A 1972 Polish paper[3] describes processes and machines for the primary working of waste fibre, and a 1972 German paper[4] describes a machine for cutting synthetic knitted fabric waste, having a cutter with sets of knives at right angles to each other. This latter paper discusses the Befarna AC-23 and AC-24 three-cylinder and four-cylinder rag-pulling machines for pulling synthetic fabric wastes, and describes a continuous processing line including a four-cylinder rag-pulling machine followed by a roller card and condenser arrangement. A patent held by Fiber Process Incorporated[5] describes a solvent extraction process under controlled heat, pressure and agitation to produce a clean fibre and a reclaimed synthetic resin from resin-coated fabrics.

The Batelle Institute Report on Solid Waste[6] briefly discusses the advantages and problems of physically separating mixed fibres into pure polymer types. They point out that separation of cotton-polyester or wool-polyester blends into pure components would greatly increase their value, but that the possibility of achieving such a separation on a commercial basis seems remote. Techniques employing electrostatic energy, differential densities, differential solubilities and selective degradation by chemicals and light are tentatively offered as possibilities.

The method of differential densities (or sink-float elutriation) has been developed on a pilot scale for separating various polymer types recovered from industrial and municipal wastes, but it is generally considered too slow and expensive a method for practical purposes. Chemical separation has been achieved on a limited scale by the selective hydrolysis of polyester fibre in cotton-polyester blends. This method involves the recovery of pure cotton fibre and terephthalic acid. Thus far no information has been found on the economic feasibility of the chemical method.

The photodegradation of cellulosics, using inorganic salts as catalysts, has been under investigation at the Gillette Research Institute. This method would, of course, involve the loss of substantial proportion of potentially valuable fibre. Selective solvent separation of the components in a fibre blend is also technically possible, although cotton, polyester and wool could cause problems due to their relative insolubility in common solvents.

A 1974 patent covering a chemical process for recovering cellulosic fibres from mixtures of waste cellulosic, polyester and/or acrylic fibres, and synthetic crosslinked resins, is held by Johnson and Johnson.[7] In this patent, waste cellulosic fibres are recovered from mixtures of waste cellulosic, polyester and/or acrylic fibres and synthetic crosslinked resin materials, by heating the mixture at 100° to 135°C for 3/4 to 5 hours in an aqueous solution of an alkali metal hydroxide and one or more liquid chemical agents such as ketones, alcohols, lactones and sulphoxides, which initiate decomposition or solubilization of the non-cellulosic materials. After addition of a neutral or alkaline oxidizing agent, the mixture is heated to complete decomposition or solubilization and the cellulosic waste is recovered.

According to a 1975 article in the Clothing Institute Journal,[8] "Fibre type sorting is likely to be extremely difficult considering the variety of types of material (both 100% synthetic and blended) likely to be encountered. Mechanization of this sorting, although possible, would undoubtedly involve extensive development. The best course would undoubtedly be fibre type sorting at the cutting room, although it seems unlikely that co-operation in this would be forthcoming from the garment industry. Blended materials pose a further problem."

A paper given by W. S. Egekvist of the Recyclomatic Company of Minneapolis called "Practical Aspects of Recycling Synthetic Fibers", identified the two most important factors of any waste utilization effort as (1) segregation to achieve uniformity of any particular type of waste and (2) large enough volume to make it worthwhile from an economic and/or social standpoint.

Considering segregation of fibre polymer types, Egekvist stressed the importance of segregation at the source. He suggested, in contradiction to articles quoted earlier, that much more could be done at this stage, and that it "just takes a little time, imagination and effort". He said that it might pay to invest more in labout in order to make the wastes marketable for recycling. Of course, separation at source would not solve the problem of fibre blends.

Where it is possible to obtain a substantial quantity of a pure fibre type, the main barrier to reutilization may be that it occurs in an unusable form. In this case it may be feasible to remelt and re-extrude the waste material, either in the form of new fibres where the waste is clean, or in the form of some other product where the waste is of lower quality. The re-extrusion of fibre is included here as an aspect of fibre recovery, while extrusion in the form of a new product is included, along with moulding, in the section on refabrication.

The Eastman Kodak Company holds a patent granted in 1974[9] for an apparatus designed to recover waste polyester fibre, particularly in large entangled masses of continuous filamentary material in either drawn or undrawn condition and to convert it into re-usable feed stock. The continuous filaments are converted into random length staple fibres, which are compacted and melted to form a melt flow, and then extruded.

A German company by the name of Sikoplast, located in Siegburg, has developed a process for re-extruding such waste fibres as polyamides, polyester and polypropylene into pellets for reuse.[10] The reclaimed material is said to be used for injection moulding and extruding a variety of shapes. In addition, development work was being carried out in 1973 on using the reclaimed materials in the melt spinning prccess from which the wastes originated. More details on the Sikoplast process are contained in section 6.2.2.

Judging from the literature, the technology for pulling and cutting waste textile fibres is available. However, it appears that the technology for economically separating into polymer types is not. It would also appear that the feasibility of separating into natural and synthetic fibres is in doubt. It would seem then, that the choice of markets for waste textile fibres is partly dependent upon three factors:

(1) the future development of effective and inexpensive separation processes,

(2) the ability to separate the textile wastes at the source, and

(3) the availability of markets for mixed textile fibres.

6.2.2 Refabrication from Wastes

The refabrication of textile wastes can result either in a re-extruded fibre which is employed in the production of more textiles, or in the production of some entirely new product. This section is concerned with the refabrication of the waste in the form of a new product.

A Polish article published in 1975[11] discusses trends in the use of waste materials in the manufacture of non-woven fabrics. In particular, problems relating to machinery are examined.

A 1973 article in Textile Manufacturer[10] describes the process developed by the German company, Sikoplast of Siegburg, for the reclamation of a wide range of textile materials. According to the article, the following materials are readily utilized: wastes produced during start-up; fibres outside the acceptable tolerance standards; wastes generated by the weaving and knitting processes; and wastes in the form of worn or discarded garments.

The Sikoplast system involves the re-extrusion of such thermoplastic resins as polyamides, polyester and polypropylene. Unfortunately, there is

no mention of processes for separating the synthetic fibres from one another or from natural fibres. Continuous filaments, short fibre, knitted or woven fabrics may, in many instances, be fed into the extruder without pre-cutting. A melt filtration system removes solid contaminants from the wastes. Thus waste synthetic fibres, filaments and fabrics are converted to regular granules which may be used for injection moulding or extruding a variety of articles.

A summary is given of the economics of the Sikoplast process based on equipment suitable for delivering 150 pounds of extruded pellets per hour. (The original figures were given in 1973 pounds sterling. They have been converted to 1973 dollars by applying the factor 2.40.)

Capital cost including installation	$40,800
Depreciation (5 years)	8,160
Interest at 10%	4,080
Depreciation and interest	12,240
Floor space, power, water maintenance, spare parts	21,600
Labour	10,800
Total	$44,640

The cost per hour at 7000 hours per annum is $6.24; therefore the cost of reprocessed material is 4.15 cents per pound.

Apparently the pellets of reclaimed thermoplastic wastes are being used for injection mouldings and for extruded sheets, sections, films, and film tapes. Development work was also underway in 1973 on using reclaimed materials in the melt spinning process from which the wastes originated.

The description of the Sikoplast process sounds almost too trouble-free. There is no mention of separating mixed fibres, either synthetic or natural, and no discussion of the problem of coloured fabrics. However, it is well known that these can be serious barriers to refabrication.

It is probable that, for the near future at least, refabrication will be restricted to wastes of a single polymer type and colour at one time. This being the case, the most suitable way of using the process would seem to be as an adjunct to regular synthetic fibre extrusion, where the scrap is re-extruded as fibre within the plant.

A fundamental objection to refabrication is that it does not take advantage of the fibre as is. A certain amount of intrinsic value or "sequestered energy" is contained in the fibres due to the original cost (in dollars or energy) of their fabrication. Not only is this value destroyed when the fibre is melted, but more energy is required to melt and extrude the polymer a second time. Thus there is a hidden advantage to utilizing the wastes in the fibrous form.

6.2.3 Fibre-Reinforced Thermoplastic Resins

Various studies have shown that organic fibres can significantly reinforce the strengths and moduli of thermoplastic resins, particularly the ductile type. Brittle matrix composites are also reinforced in strength when the ultimate elongation of the matrix is substantially greater than the fibre ultimate elongation.[12] It has also been demonstrated that organic fibres, such as polyamide or polyester can contribute a substantial increase in toughness to semi-crystalline polymer matrices as measured by the notched Izod Impact test.[13] This work was done using both continuous and discontinuous fibres, on samples prepared by hand layups of laminated structures followed by compression moulding; and also, using discontinuous fibres only, by compression moulding mixtures of oriented fibres and powdered resins.

A study carried out in the laboratories of De Bell and Richardson[14] determined the effects of scrap organic fibres and cloth on two thermoplastics (low density polyethylene and polyvinyl chloride) and one thermoset. It was found that organic fibres reinforced low density polyethylene but provided little reinforcement to polyvinyl chloride. The fibres (polypropylene, polyamide, polyester, acrylic and acetate, and macerated cloth) significantly

increased stiffness and improved dimensional stability in low-density polyethylene, but in most cases, except for polypropylene, lowered melt flow. Fibreglass behaved similarly but showed the best overall properties. Fibreglass properties were, however, approached by acrylic and acetate fibres. The acrylic gave the best physical properties of the organic fibres, while the acetate fibres provided much better melt flow with good properties. In this study the polyvinyl chloride and polyethylene compounds were milled on a two-roll differential speed-mill, following which they were compression moulded.

It will be observed that in all the above studies the specimens were hand rather than injection moulded. This brings us to one of the major problems involved in utilizing organic fibres in thermoplastic resins: the fact that the nozzle on the conventional moulder tends to hold back the organic fibres. However, it is understood that work is being done to overcome this serious drawback, and it is hoped that discontinuous organic fibres will soon play a role in the reinforcement of injection-moulded thermoplastic resins.

Despite these problems, there is one company that appears to have had some success in the injection moulding of test specimens. This is the American Enka Company, which produces a polyethylene terephthalate fibre with the trade name "Encron" for reinforcement purposes. Although their literature contains no description of the procedure used, the statement is made that "Encron has no tendency to fragment during injection or transfer moulding."[15]

In considering the type of application in which fibres from textile wastes would be suitable, the same situation is encountered with the thermoplastic resins as with the thermosets, that is, a high performance or engineering application requires a high performance fibre with a high degree of predictability, which in turn demands uniformity of polymer type and fibre dimension. As explained in section 6.2.1 such a uniformity is unlikely to be economically achieved on a production scale in the case of waste textile mixtures and blends.

It would be more realistic to consider the utilization of the waste fibres in less critical commodity applications. These applications might tolerate such mixed synthetic fibres as polyester, nylon and acrylic, cellulosics such as rayon, and possibly the natural fibres, wool and cotton.

A 1975 Russian article[16] describes the use of waste products from the viscose rayon industry (acid fibres, neutral fibres, filaments, staple fibres and tire-cord yarns) in the production of fibre-reinforced plastics which can be employed in the building and engineering industries. In this case only one polymer type from a single industry is involved, so that the problem of mixed fabrics and mixed fibre blends does not come under consideration.

An interesting application which could have significance for chopped mixed waste textiles is the subject of a German patent.[17] In this application various fibres were used to reinforce vinyl tiles of the type used as floor covering. A mixture of limestone, titanium dioxide pigment, vinyl chloride-acetate copolymer, a hydrocarbon resin, a tall oil resin, a melamine stabilizer, an epoxidized soybean oil, an ester plasticizer and the fibres was milled at 71-88°C and made into files. The reinforcements used were polyamide, polyester and cotton fibres, and the tiles were found to have better dimensional stability and indentation and abrasion resistance than control samples containing asbestos fibres.

Some work was done at the Ontario Research Foundation with fabric wastes consisting of 65% polyester and 35% cotton. The idea was to prepare moulded specimens using the polyester as matrix and the cotton as filler. Two different samples of the ground fabric were prepared, one passing a 1 millimetre sieve and the other a 6 millimetre sieve. They were prepared by mixing in the melt at 260°C followed by grinding in a Wiley mill. They were then sieved and compression moulded at 260°C. A smooth platen resulted, showing possibilities for a material that might be either extruded or injection moulded. More work should be done to determine the amount of grinding required to reduce the cotton to optimum fibre length.

The Russian article and the German patent demonstrate that there is a role for organic reinforcements in thermoplastic resins, even though this role is limited at present by the difficulty of injection moulding. In the case of waste textile fibres a second barrier is encountered in the mixed nature of the material. As pointed out earlier, it is extremely doubtful that the separation of polymer types can be achieved economically on a production scale. If the fibres can be separated at source it might eventually be possible to exploit the thermoplastic market.

There does appear to be an appreciable market for totally mixed fibres (natural and synthetic) in such products as reinforced vinyl floor tile. This is probably one of the best uses to which waste textile fibres could be put at the present time.

6.2.4 Fibre-Reinforced Thermosetting Resins

Most of the applications in which organic fibres are used to reinforce thermosetting resins demand continuous rather than discontinuous reinforcement. The majority of these applications make use of specially prepared continuous high modulus fibres, such as polyaramid, to provide the special properties desired. Such applications would be in the high performance or engineering category.

Engineering composites could also probably use discontinuous organic fibres for certain applications. However, the required high performance and predictability of properties in an engineering composite demand uniformity of polymer type and fibre dimension. This is very unlikely to be achieved with mixed or blended fabrics because of the difficulty of separating polymer types, as pointed out in section 6.2.1.

A literature search on organic fibre reinforcement, from wastes, using the on-line bibliographic information retrieval system, failed to produce anything very helpful: virtually all of the literature on reinforced thermosets dealt with continuous high modulus fibre reinforcement. A manual search through the last five years of World Textile Abstracts produced only

a Russian article of 1975 on the manufacture of fibre-reinforced plastics for the building and engineering industries.[18] This process used waste products from viscose rayon production, consisting of acid fibres, neutral fibres, filaments, staple fibres and tire cord yarns. As only a single polymer type was utilized, there were no problems of separation or sorting.

Despite the dearth of literature on the subject of waste textile fibres as reinforcements in thermosetting composites, there are some possibilities which do come to mind. One is the use of such fibres in flock form, to replace asbestos in composites as an agent to prevent the separation of glass fibres from the resin during moulding. It is possible that there might be some problems with water absorption. If so, can the textile fibres be made hydrophobic?

Small pieces of fabric, about ¼ inch square, might be used as reinforcement with polyesters or phenolics. It could be very useful to fabricate phenolic or polyester composites with glass microballoons and small squares of fabric. If high volume loading can be achieved, the product could have a use as an inexpensive insulating panel. Water absorption and flammability are problems that would have to be solved, and techniques would have to be developed to ensure optimum packing in order to reduce resin content and therefore cost.

The lack of information on the use of waste textile fibres as reinforcements in thermosets means that some work should be done to evaluate them in this capacity. Stiffness, strength and impact strength should be determined on composites containing typical mixed fibre types. A knowledge of the physical properties of such composites and the problems and economics of processing would help to provide guidelines for future utilization of the wastes in composite materials.

6.2.5 Insulation and Panel Board

Two types of insulation were considered: loose fill and low density board. Loose fill insulation, such as vermiculite, rock wool and glass wool, has long been used for insulating walls, attics and crawl spaces. More

recently, cellulose fibre from waste paper has been used for the same purpose. When treated to provide a degree of fire retardency, the cellulose fibre makes an effective, safe and economical loose fill insulating material.

There would seem to be no reason why waste fabrics, when subjected to the appropriate mechanical action and treated, could not be employed as loose fill insulation as effectively as paper fibre. Indeed, textile fibres would seem to have several advantages over paper fibre, such as lower moisture absorption and less attraction for mice and other vermin. The processing of the textile fabric, which would mainly involve pulling, chopping or some other mechanical action, would be similar in its simplicity and economics to the dry defibration process required of waste newspaper. It is believed that the insulating value of textile fibres would be similar to that of paper fibres. The major market advantage of such an application is that it is a high volume use and in high demand due to the current need for energy conservation. In order to compete in this market it would have to meet the paper fibre price of $40 per ton.

Another product which will probably be in high demand is low density insulating board. This probably could be fabricated from woven and knitted fabric wastes which have been subjected to a simple pulling action in order to separate the individual strands from one another. If the strands were formed into an appropriate shape with a resin binder, a rigid insulating board or other useful product could be formed. One possible application might be as a semicylindrical rigid insulation for pipes.

This type of utilization of waste fibres has not escaped notice in Europe. A British patent[19] covers a process for the recovery of fibres from more complex mixtures than we are dealing with here. In this process household, agricultural or industrial waste is treated with a solvent to dissolve some of the unstable components, following which it is dried, comminuted and subjected to partial aerobic decomposition, and finally heated to a temperature above 100°C. The resultant fibres are mixed with a binder such as urea formaldehyde or phenol formaldehyde resin, and formed into "panels, boards, insulation or filler material".

Another possible product, which is somewhat similar to insulating board, is a higher density panel for partitions or ceiling tiles. Actually, a whole gradation of boards of different densities is possible depending on the properties desired. Various types of thermal and accoustical insulation products could be fabricated depending on the appropriateness of the waste fibres and the demand of the market.

A German manufacturer of auxiliaries and chemicals for the textile industry, Syntex Chemie GMBH, has built a plant for the processing of textile, floor covering, carpet and non-woven wastes. According to their literature the wastes can be made into sheets, slabs, blocks and moulded materials.

The fabricated structures are said to be useful for the following types of applications.

(1) Insulating sheeting for sound-proofing and thermal insulation

(2) Insulating sheets laminated on one or both sides

(3) Prefabricated structural elements such as partitions with or without laminated surfaces

(4) Furniture elements with the same or different lamination on both sides

(5) Prefabricated elements for prefabricated homes, e.g. casings for shutter screens, doors

(6) Parts used in road building, such as foundation slabs

(7) Slabs or stones to absorb vibration

(8) Covers for high-noise level machinery

(9) Insulation moulds for canals, plumbing systems, plant-apparatus, boilers and automobile construction as thermal or sound insulation

(10) Floor slabs with laminated carpeting

(11) Foundation insulating slabs

(12) Building blocks to replace bricks

(13) Packing materials, pallet plates

(14) Doors and partitions

(15) Reinforced supporting elements for machine and building construction and civil engineering

(16) Facade and insulating slabs

(17) Roofing material, suitably laminated

If necessary, these products can be made fire-retardant.

The large number of potential products would appear to make this type of utilization one of the most hopeful for textile wastes.

6.2.6 Fibre-Reinforced Inorganic Construction Materials

Work has been done on organic fibre-reinforced cement and concrete in both Britain and the United States. A 1973 doctoral thesis by M. K. N. Iyengar[20] of the University of Delaware reported the results of a study on the effect of various percentages of nylon fibres on concrete. A 1974 Shirley Institute Conference held in Manchester, England, with the general title Fibres in Civil Engineering,[21] covered many aspects of this broad subject, including the use of organic fibres in building materials. A 1975 article in Composites[22] examined cement-based composites containing mixtures of different types of fibres, including nylon and polypropylene. This study

found that organic polymer fibres, when added to cement or concrete even in small proportions, substantially improved the impact resistance of the matrix but had very little effect on the tensile or flexural strengths. The improvement of these latter two properties was accomplished by the addition of a second fibre such as glass, asbestos or carbon. The paper concluded that it is possible to produce superior cement-based composites by including a mixture of organic and inorganic fibres as reinforcements. Although the lengths of the fibres are not given in the article, they probably should be fairly long to prevent pullouts during the impact and flexural strength tests.

Some work would have to be done to determine whether the textile wastes are suitable for the reinforcement of concrete and cement.

6.2.7 Organic Fibre-Reinforced Rubber

Organic fibres have long been employed as reinforcement in rubber products. Originally cotton was used, but this has now been replaced by rayon, nylon, polyester, glass, steel and polyaramid. In all cases these reinforcements have been used in the form of continuous filaments.

The main reasons for employing continuous as opposed to discontinuous reinforcements are (1) that the long filaments provide superior reinforcement in the typesof products being fabricated, such as high pressure hose and power transmission belts (partly because they are easily oriented), and (2) that long filaments are more easily accommodated in the manufacturing process. An example of this latter observation is the "dipping" process whereby the reinforcement is coated with a rubber latex in order to provide a bonding surface between the filaments and the rubber matrix. The dipping is most easily accomplished by passing the continuous strands through a tank of the latex on their way to the moulding operation. The machinery for this is already in existence, while a production technique for dipping discontinuous fibres would have to be developed.

Some work has been done by the rubber companies on the utilization of discontinuous organic fibre reinforcements in rubber, but the inadequate physical properties of the composites and the production and economic

realities of discontinuous fibres resulted in abandonment of the work. Because of this justifiable lack of interest on the part of the rubber companies in discontinuous fibre-reinforcing, it would appear, for the present at least, that there is no market for textile wastes in the rubber compounding industry.

6.2.8 Fibre-Reinforced Asphalt Floorings

There are several asphalt products which utilize low grade fibres, such as planking used for recreational flooring, heavy-traffic flooring in warehouses, and underlays for tiles or linoleum in basements. Some work has been done at the Ontario Research Foundation on the utilization of the non-metallic fraction from an auto shredding plant in such an application. This fraction, usually referred to as "dirt", contains a high proportion of fibrous material.

The dirt was screened into several fractions and the -4 mesh material used with asphalt in the preparation of test specimens. It was found that the -4 mesh fraction-asphalt composite exhibited properties very similar to those of commercial asphalt recreational planking.

The purpose of the study was to find an alternative to disposal of the non-metallic fraction by landfill, which costs about $5 per ton for trucking and dumping. It can be seen that economically this is a very low grade type of use. It is only suggested here as a possibility in case the textile fibres are found unsuitable for a higher quality application.

6.3 Sources of Information

Three literature sources were employed in the preparation of this report:

Chemical Abstracts 1970 to present
Engineering Abstracts 1970 to present
World Textile Abstracts 1972 to present

The Chemical Abstracts and Engineering Index were searched using the on-line bibliographic information retrieval system, by means of the following key words and logic.

(1) Organic and Reinforc* and (fibre or fiber)
(2) Waste and Utilization and (garment or fabric)

World Textile Abstracts was searched manually, from 1972 to the present.

REFERENCES

1. A. Hengel, Process for Dividing up Waste Textile Pieces, British Patent 1,264,366: 23 February 1972; Application (Germany No. P1685551.9 and P1760403.4) 27 February 1968 and 14 May 1968.

2. Du Pont of Canada Ltd. and H. J. Fairfield, Conversion Process and Apparatus for Textile Fibres and Discontinuous Filaments Produced Therefrom, British Patent 1,305,397: 31 January 1973; Application (no. 2313/70) 16 January 1970. Also: U.S. Patent 3,653,094: 4 April 1972; Application (no. 878,826) 21 November 1969.

3. H. Wlodarczyk, Processes and Machines for the Primary Working of Waste Fibre, Prezeglad Wlokienniczy, 1972, 26, No. 6,300-304 (5 pages). In Polish.

4. B. Sikora, Economic Utilization as Raw Material of Textile Waste Consisting of Synthetic Fibres, Deutsche Textiltechnik, 1972, 22, No. 12, 744-746 (3 pages) In German.

5. Fiber Process Inc., W. B. Sussman, C. D. Belcher, and G. E. Brown, Method for Reclaiming Commercially Useful Fibers and Resin from Scrap Material, U.S. Patent 3,624,009: 30 November 1971; Application (No. 873800) 4 November 1969.

6. Battelle Memorial Institute, Columbus Laboratories, Prepared for Environmental Protection Agency, A Study to Idensity Opportunities for Increased Solid Waste Utilization, Vol. IX. Distributed by the National Technical Information Service, PB-212731.

7. Johnson and Johnson and A. T. Mays, Methods of Recovering Waste Cellulosic Fibres, U.S. Patent 3,801,273: 2 April 1974; Application (No. 285,388) 30 August 1972.

8. G. Lund, "Recycling in the Garment Industry", Clothing Institute Journal, 23, No. 2 (1975), p.99.

9. Eastman Kodak Co., R. Hester and H. P. Pierson, Thermoplastic Scrap Recovery, British Patent 1,368,488: 25 September 1974; Application (U.S. No. 67324) 27 August 1970. Also U.S. Patent 3,795,468: 5 March 1974; Application (No. 286,492) 5 September 1972.

10. Anon, "Recovery of Waste in the man-made Fibre Industry", Textile Manufacturer 1973, 100 (September 20) (1 page).

11. W. Jedrzejewski and H. Wlodarczyk, "Waste Materials in the Production of Nonwovens", Technik Wlokienniczy 1975, 24 No. 11, pp.305-308. In Polish.

12. Bruce F. Blumentritt, Stuart L. Cooper, "Discontinuous Organic Fiber Reinforced Thermoplastics", Society of Plastics Engineers 32nd Conference, 20, May 13-16, 1974.

13. M. R. Kantz, R. D. Corneliussen, "The Mechanical Properties of Organic Fiber Reinforced Polypropylene Composites", American Chemical Society, Div. Poly. Chem. Prep. 14, No. 1 (1973).

14. Bernard Baum (De Bell and Richardson Inc.) "Organic Fibres as Reinforcement in Plastics", paper presented at the August 1973 meeting of the American Chemical Society, Division of Organic Coatings and Plastic Chemistry, Vol. 33, No. 2.

15. American Enca Company, Encron, a Fibre for Reinforced, Moulded Plastics

16. S. E. Artemenko et al, "Utilizing the Waste Products from Viscose Rayon Production", Khimicheskie Volokna 17, no. 5 (1975) pp. 52-53. In Russian.

17. George W. Loosemore (Armstrong Cork Co.), Organic Fibre-Reinforced Vinyl Tiles or Plates, Ger. Offen. 2,050,510, 22 April 1971, U.S. Application 15 October 1969; 14 pp.

18. See reference 16.

19. Jetzer Eng. A. G., Recovery of Fibres from Waste Material, British Patent 1,448,123: 2 September 1972; Application (Switzerland no. 17607/72) 4 December 1972.

20. M. K. N. Iyengar, Organic Fibre-Reinforced Concrete 1973, University of Delaware, Faculty of Civil Engineering, Ann Arbor, MI: University Microfilms International.

21. Shirley Institute Conference 18 June 1974, Fibres in Civil Engineering, Shirley Institute, Manchester, England, (Shirley Publication S18).

22. P. L. Walton and A. J. Majumdar, "Cement-Based Composites with Mixtures of Different Types of Fibres", Composites, September 1975.

M. J. Williams,
Program Coordinator.

APPENDIX

INTERVIEWS WITH SELECTED ONTARIO BASED TEXTILE WASTE PRODUCERS AND USERS

WASTE PRODUCERS

CARHARTT, River Street, Toronto

Interview - Doug Manchester
Product - Pants: 1. 100% cotton denim
2. 84% cotton/16% polyester corduroy

Segregation of cuttings takes place in production because the two fabrics are used seasonally. They make no particular attempt to separate waste if they are cutting more than one fabric in the plant.

Cuttings are deposited directly into bags, from the cutting table.

Sell all waste cuttings to Dominion Burlap.

Do not know whether D-B separate, or what they do with the waste.

APPLE-BEE SHIRTS, 555 Richmond Street West, Toronto

Interview - Gary Kates
Product - Shirts: 1. 100% cotton - coloured
2. Polyester/cotton - coloured

All cuttings are put into bags in the cutting room and dumped. They used to give waste to Dominion Burlap but D-B stopped pickup, and as Apple Bee needed space, they dumped waste, and have been doing so ever since.

Each type of fabric is used separately, by season. Kates is unaware of potential value of 100% cotton, and gives no consideration to waste salvage, because it was assumed that there was no value. This assumption may have been influenced by waste dealer.

Kates, in my presence, issued instructions to make investigation.

G.W.G. (Eastern), Edward Street, Brantford

Interview - Dave Marshall, plant manager
- recently arrived from Edmonton branch; not familiar with Brantford operation
Product - Pants: 1. 100% cotton denim
2. 84% cotton/16% polyester corduroy
3. Some other blends but always majority cotton

Similar production setup as Carhartt. Cutting waste deposited into bags directly from table, but dumped. Dominion Burlap apparently not interested. The history is that they used to sell waste to D-B but D-B discontinued pickup so, as space capacity is critical, they dumped and have been doing so ever since.

All the elements exist within the plant for shipment of reasonably separated waste, but no apparent market exists. As this pertains in Edmonton, Marshall has assumed the same is true in Brantford. He issued instructions to investigate in my presence.

Marshall is concerned with ecological impact of waste dumping but inclines to the view that it is a Government responsibility, or at least requires Government initiatives.

TERRY WILLIAMS KNITTERS, Kitchener

Interview - Terry Williams
Product - Men's Sweaters: 1. 100% wool
2. 70% acrylic/30% wool

All waste which is of comparatively soft nature is collected, sorted as produced and sold to Ferguson, O'Reilly, Elmira, Ontario, who presumably use it to make cheap yarns spun (by them) on the woollen system. Williams said that occasionally the price of some waste is so low as to be uneconomic of recovery but overall is always profitable. He is sure that his waste is marketable because of the wool content.

CLUETT PEABODY (Arrow Shirt), Kitchener

Interview - Hofstedder
Product - Shirts: 1. Majority polyester/cotton
2. 100% cotton

All fabrics are light weight shirtings, mostly coloured. Despite continuing efforts, they have not been able to establish a market for their waste. Consequently they organize production and waste collection as efficiently as possible without any regard to salvage. Fabric cutting creates mixing effect; all waste goes to floor, and is swept up at end of each shift, packaged and dumped. They pay municipal dumping tax. They are aware of the waste they create and want to salvage from both ecological and economic points of view.

KRAUS CARPET, Waterloo

Interview - Nelson Kraus

They control three companies that all produce waste:

1. Kraus Carpet

Product - Carpet

Most of the waste product which is not recycled is carpet selvedge, a waste product of carpet trimming. This consists of rubber, burlap, polypropylene and nylon, all mixed. They cannot separate it and there is no market for it.

They recycle or sell all waste possible.

2. Strudex

Extrudes polypropylene into continuous filament form. They dump poly "lumps".

3. Waterloo Spinners

Spinners of staple fibres, mostly polyamide.

Summary

Kraus says they are intensely conscious of value and responsibility aspects of waste recovery and are doing their best, but would welcome assistance.

WARREN K. COOK, Fraser Avenue, Toronto

Interview - Carl Spazianni
Product - Men's suits: 1. 100% wool
2. Majority wool/polyester

All waste is collected, sold and taken away by a waste dealer. They have never had any difficulty in selling waste. They do not segregate waste by fibre type but they do protect its value by keeping it off floors. They know the high value of wool is reason they have no difficulty in selling their waste.

FUTURAMA KNITTING MILLS, Richmond Street West, Toronto

Interview - Forelady
Product - Knitwear: 1. 100% acrylic
2. Majority acrylic/polyester

All waste, which is of a comparatively soft nature, is separated as to type of fibre or blend and sold to Granatstein & Son. Separating is done at the request of Granatstein and probably enhances the marketability. Granatstein, who was also interviewed, said that there is a good demand for knitwear waste. They spin yarn from it and also export this material.

GRANATSTEIN & SON

Interview - S. Granatstein
Product - Textile waste dealer & converter

Buy wastes and convert them into fibre for spinning, which they sell and also use for own spinning operation.

Mr. Granatstein made interesting observations.

There is very little market for hard waste (woven) except 100% cotton, and 100% wool and wool blends.

Before the advent of polyester and polyamide fibres, cotton fabric waste, like shirting, was used in the manufacture of fine paper. The inclusion of these synthetics now precludes the use of most shirting and dress fabric cuttings for that end use.

There is no market for 100% polyester, either woven or double knit. The comparatively soft nature of sweater knits and yarns are suitable for reduction by garnet machine into soft fibre for woollen system spinning. Granatstein would not directly say how far afield he will go for this type of waste, except to say that there was a balance between transportation cost and supply and demand situation. Clarification of this question can be answered by outlying knitwear manufacturers.

WASTE UTILIZERS

LALOR AND COMPANY - John Lalor

A company dealing in all types of hard and soft waste textile materials.

1. Sorting. Company usually buys only sorted waste because sorting is too costly.

Exceptions: Waste containing wool - (wool content)
: Large, simple sorting for special orders, e.g. Export

Note: A producer of waste, i.e. garment maker, spinner, knitter, etc., will only sort waste if it is economical to do so. There is an equation made up of sorting labour cost, quantity of waste, and market value of the product. Some manufacturers can organize production so that waste is kept separate as to type; but some do, some don't. Lalor believes that many manufacturers are unaware of the potential value of their waste products.

2. Transportation. Most waste is delivered to Lalor's premises, but they do pick up, locally, if volume and value justifies. High transportation costs mitigate against all waste recovery outside of large centres except when large volumes are involved.

3. Market. The normal ebb and flow of the textile market affects their business. However, they are rarely unable to obtain enough waste to meet market opportunities. They stockpile to some extent, based on market expectations, or buying opportunities. The export is very much an opportunity market.

Lalor's opinion. Manufacturers might make more effort to recycle waste if they understood the problems better, e.g.:

Sorting during production
Stockpiling
Compress baling

LEIGH TEXTILES - BURLINGTON - Mr. McKenna Local Rep. for Mtl. based Co.

McKenna deals mainly in soft waste, i.e. waste from spinning and other raw fibre converting, and hard waste that can be converted into soft waste.

His opinions are:

1. There is very little of this type of waste that is not recycled.
2. Most textile waste, i.e. garment fabric waste, is collected by:

   Large sources - waste dealers directly
   Small sources - junk dealers, who sell to waste dealers

3. There are large quantities of unrecyclable waste, e.g.:

   a. Textiles contaminated with rubber backing - carpet clippings
   b. Non-convertible plastics - polypropolene bagging

c. "Round fibre", i.e. fibre too short for processing - velour and pile fabric shearings

This company is Montreal based. Mr. McKenna's knowledge seems to be rather specialized.

CANADA FELT CO. - Mr. Rais and Mr. Wolfe

This company's market is mainly material for quilting and bedding, such as mattress covers.

Men of long experience, but restricted to their market.

Mr. Wolfe is particularly concerned about the ecological effect of waste generation and disposal. Of strong European ties, he holds that North Americans are living beyond their means and must follow European examples of waste disposal. He did not elucidate these methods. Mr. Rais did not share this view, but both stated that "Government" should prohibit dumping of textile waste. It is their contention that many garment manufacturers make no effort to initiate textile waste recycling, because they believe it is not economic to do so. They suggest that some company officials are ignorant of the potential for waste recovery, and/or are prevented from initiating waste recovery by offshore owners (U.S.?).

Their proposals for waste recovery are:

1. Place a penalty on waste dumping by imposing a heavy dumping charge.

2. Government take over textile waste collection, and:
   a. Sell to existing waste dealers, employing U.I.C. applicants to man transport trucks, sorting and warehousing.
   b. Develop new methods of recycling presently unrecyclable materials.
   c. Change definition of waste not worn by humans from "used" to "new", to allow greater use of textile waste in quilting and bedding.

These opinions are reported verbatim; one must recognize the possibility of bias due to vested interest.

Presented

by

Dr. O. A. Battista
Chairman of the Board
President and Chief
Executive Officer

RESEARCH SERVICES CORPORATION

FORT WORTH, TEXAS, U.S.A.

Director, Center for Microcrystal
Polymer Science,
University of Texas,
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"MICROCRYSTAL POLYMER SCIENCE - A NEW ROUTE TO USEFUL PRODUCTS FROM WASTE TEXTILE"

Microcrystal Polymer Science, By O. A. Battista, published by McGraw Hall, 1975, ($18.50), is the only definitive book on this subject. Anyone wishing to study the available literature, learn about the growing number of commercial products based on this new branch of polymer science may wish to study a copy of this book in their library.

at the

UTILIZATION OF TEXTILE WASTE SEMINAR

June 20-21, 1977

Victoria Hall
Queen's University
KINGSTON, ONTARIO

It is a particular pleasure for me to participate in a program such as this today which I believe is the opening gun for a whole new science for the future, a science dedicated to squeezing resources from products which we are presently crassly throwing away. Actually, this is a subject that has excited me from April 20, 1955, when microcrystalline celluloses were discovered. I hope that some of my enthusiasm for this subject and the free thinking that I am going to give you today in the form of related ideas will spark some serious follow up interest.

First, I must explain to you, by very simple models, that a long chain polymer is something like this, schematically represented by a long string of paper clips. This polymer happens to have "paper clips" made of anhydrous glucose units (cellulose). Molecules hooked together in nature (or man) are strung together laterally like this. If they are of high enough molecular weight and the molecules have the right stiffness, you get bundles of chains bonding usually side-by-side to produce crystalline and amorphous regious.

Conventional polymer science is a fifty billion dollars/year industry in the United States. From the early thirties, through Caruthers and up until today, conventional polymer science has been based on making molecules long enough to bond laterally into structures that will form fibers or films.

What I want to tell you about today is something that is exactly the opposite of conventional polymer science, and it all started accidentally.

I think that the important thing I should illustrate for you is what we do with science of microcrystal polymers. We start with a film fiber, or resin that already has crystalline regions or crystals preformed in them, having fixed dimensions. Then, by very careful and selective chemical or mechanical methods of attack, we remove or unhinge the hinges. Once this is done, we usually mechanical sheer forces to recover microcrystals that are almost identical in size and shape to the original dimensions in the precursor man-made or natural polymer.

Individual polymer crystals range in size from one hundred Angstroms to five thousand Angstroms. When these macromolecular crystals are dispersed in water, a fascinating new colloidal phenomena occurs.

As a matter of fact, in the earlier days when whis science was being developed, people would wonder why, after going to great lengths to make strong fibers by making the molecules long and strong, we then would destroy these fibers or films to recover powders from them! What good are these polymer powder?", they would ask. This of course, has been the philosophy of the textile fiber industry for the part fifty years. They wanted longer fibers, stronger fibers, more flexible fibers; they didn't want powders or short fibers.

In 1955, DuPont entered the tire cord market with an extremely excellent nylon tire cord; at that time the annual rayon tire cord market in the United States was about three hundred million dollars. Our management immediately became distressed about nylon tire cord. They were afraid that they would lose the rayon market very rapidly to this new competitor. They asked the scientists in our research laboratories to "start thinking about some way to become more competitive with nylon."

Our original experiments began with what we have named level-off degree of polymerization celluloses. These special hydro cellulose products were known for a long time, but nobody had ever found any use for them. They were used mainly in extremely dilute suspensions to study the morphology and fine structure of cellulose of fibers.

My original idea was to produce extremely tiny fragments of cellulose crystals and then seed them into the viscose spinning solution from which rayon fibers are made. The "seed crystals" would be small and more perfect, and approximate nylon microcrystals; we knew the reason that nylon tire cord was superior in impact and flex strength to rayon, was because the crystals of nylon were very tiny and very perfect. Nylon tire cord had many more hinges than rayon tire cord fibers. The main reason rayon replaced cotton, as a matter of reflection, was because the crystals in cotton were much bigger than the crystals in rayon! Rayon crystals were so much smaller

than the crystals in cotton, that more "hinge" areas could form so that the rayon had more flex life than the cotton. Nylon came along with a morphology even better than rayon, one took another jump in having greater resilience, toughness, and flexibility.

One day I asked an assistant, (Miss Patricia Smith) very specifically, to take 40 grams of level-off DP wood pulp cellulose and put it in a Waring blender with 400 ml. of water so that she had 10% by weight. I told her to run the blender for thirty minutes, minimum; this was to be the simple experimental out of which has come more than twenty years of research by myself and numerous co-workers.

The technician came back to me after thirty minutes and said, "Dr. Battista, what you said would happen didn't happen. I have here nothing but a pile of junk. Shall I throw it down the sink and start all over?". When I looked at what she showed me in the Waring blender, I said, "Pat, this is the most beautiful thing I have ever seen. You have here a lard-like form of pure cellulose which doesn't have a calorie in a carload." What we saw was a type of gel. (See Figure 1), which is nothing but a suspensoid of water and colloidal microcrystals of cellulose; it was strictly a physical and colloidal phenomenon sent us off at a tangent. The rest of the lecture will be concerned with the fascinating developments that occurred as a result of the pursuit of this tangial observation.

... 5

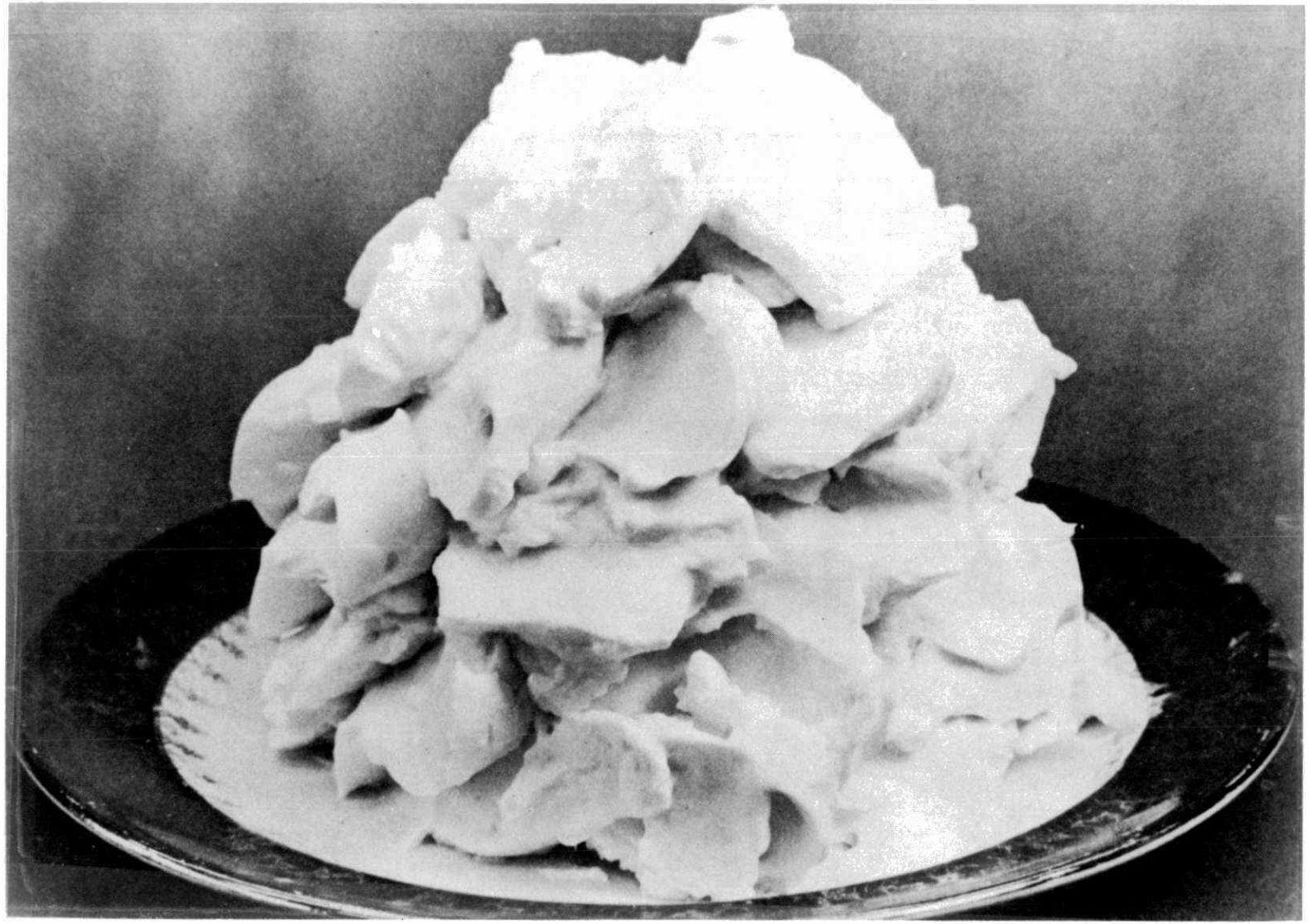


Figure 1. Avicel gel
(approx. 15%)

May I begin by saying that since 1955, (it took seven years to convince anybody that I had anything good) microcrystalline celluloses have been sold in excess of 150 million pounds. Plants in the United States, Japan and Ireland are continuing to produce the product at maximum capacity.

Figure (2) shows the major classes of products that have been converted into their respective microcrystalline forms. The explanation for the "AVI" prefix in this list of products is that it already was a prefix of hundreds of trade marks of the American Viscose Corporation. Rather than invent new names, we just continued on with using the cleared "Avi" prefixes to avoid trademark problems.

Following our work with celluloses or the polymer precursors, we then converted amylose starches into colloidal gels. We have even taken chrysotile asbestos converted it into lard-like water suspensions. The product that is extra special to me, and one now saving lives everyday, is microcrystalline or microfibrillar collagen. Known as Avitene Hemostat, it is now approved for use by the U.S. Food and Drug Administration as a hemostat for surgery.

The next three products in Figures 7, 8 & 9 should be of special interest to this audience. Crisco - like gels can be produced from every one of them, from nylon, "Aviamides"; from polyesters, "Aviesters"; and from polypropylenes, "Aviolefins."

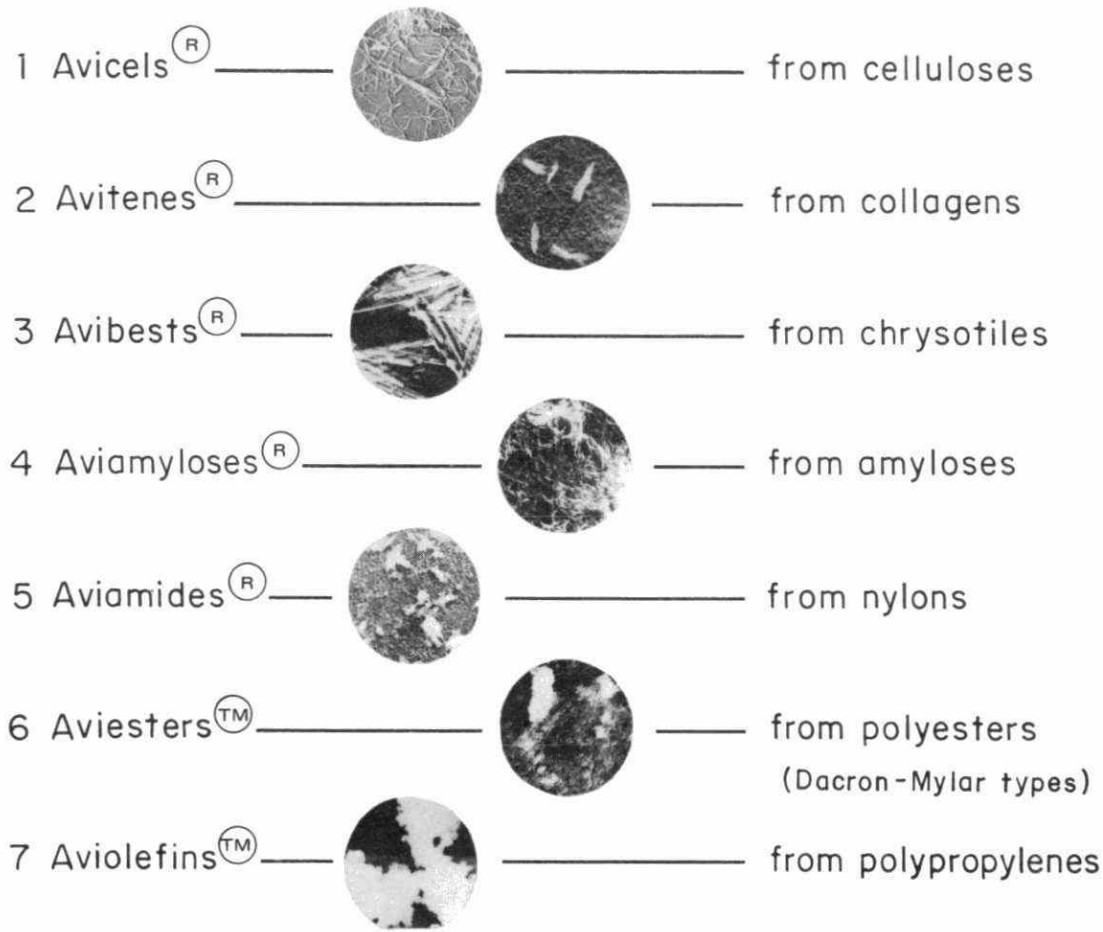


Figure 2. Family of Microcrystal Polymer Products

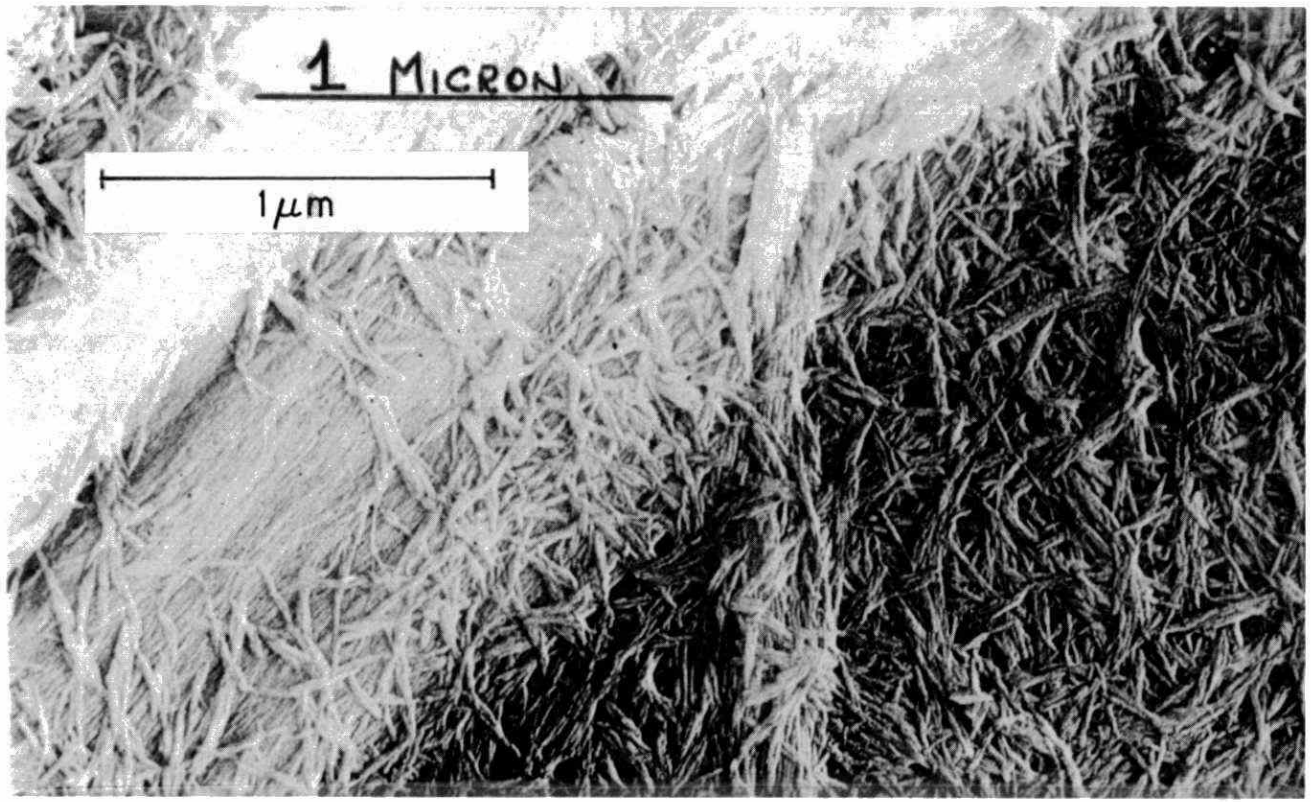


Figure 7. Single Microcrystals
of Cellulose dispersing into
Aqueous Medium

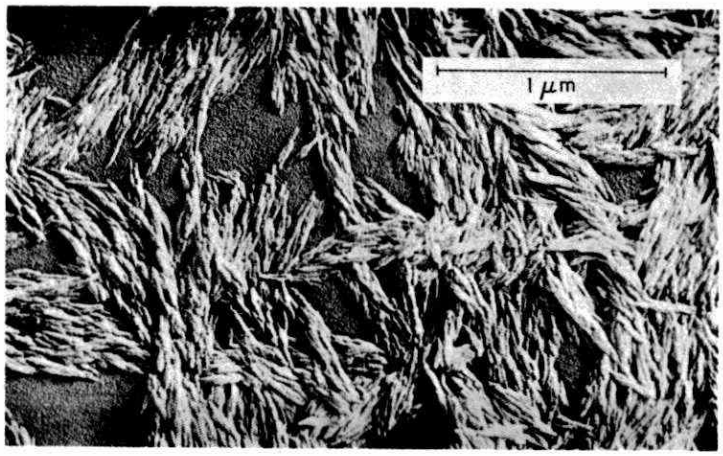


Figure 8. Cotton Cellulose
Microcrystals

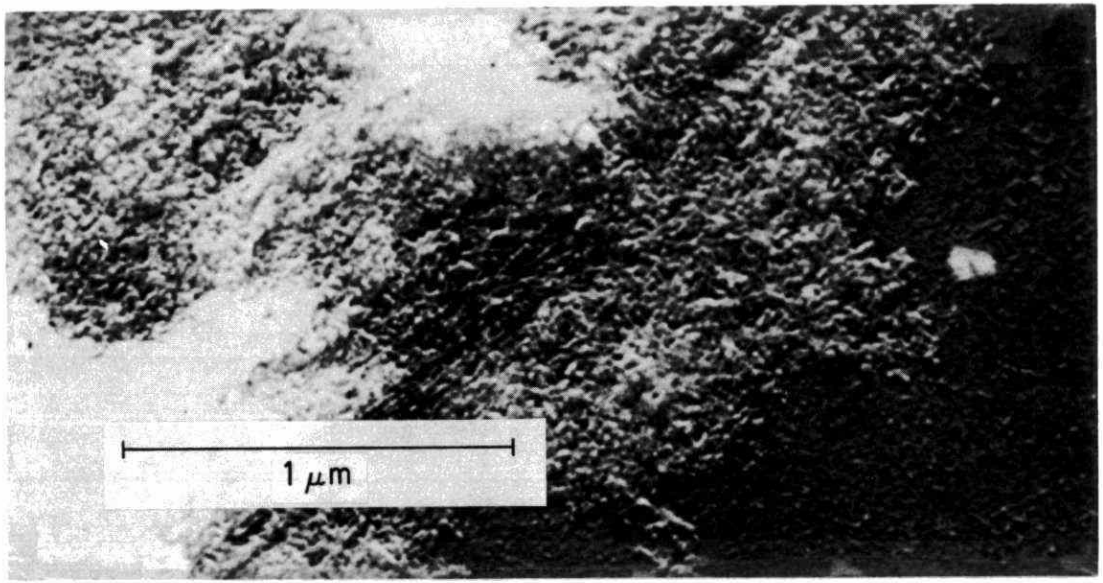


Figure 9. Rayon Cellulose
Microcrystals (50 MX)

Two of the newest microcrystal polymer products are not illustrated here. They are of more recent vintage and they are microcrystalline wool and microcrystalline silk.

Of course, electron microscopy is one of the main tools for studying this science, and I have in my portfolio thousands of electron micrographs of polymer microcrystals. By way of perspective in interpreting, these micrographs, we must remember that one inch is too hundred and fifty-four million Angstroms. (254,000,000 Å) (Figure 3). A nylon-6 microcrystal is about two hundred Angstroms; this means that you could line up at least one million nylon microcrystals side by side and they would not quite fill the space of an inch. Putting at another way, all of our microcrystals fall in the size dimensions of viruses and most bacteria, or roughly from fifty Angstroms up to five thousand Angstroms or more. The larger microcrystals, up to one micron or more, do not form nearly as smooth and stable brush-heap colloidal suspensoids as the small ones.

Figure (4) is the raw material for Avicel microcrystalline cellulose, a standard alpha cellulose wood pulp which is used to manufacture rayon or cellophane. If you take alpha cellulose and beat it and beat it, you always continue to produce finer fibril strands as shown, but you'll not unhinge the constituent microcrystals. That is why the best you can do by beating pulp is make a paper mache when you dry it. Now, if you attack the wood

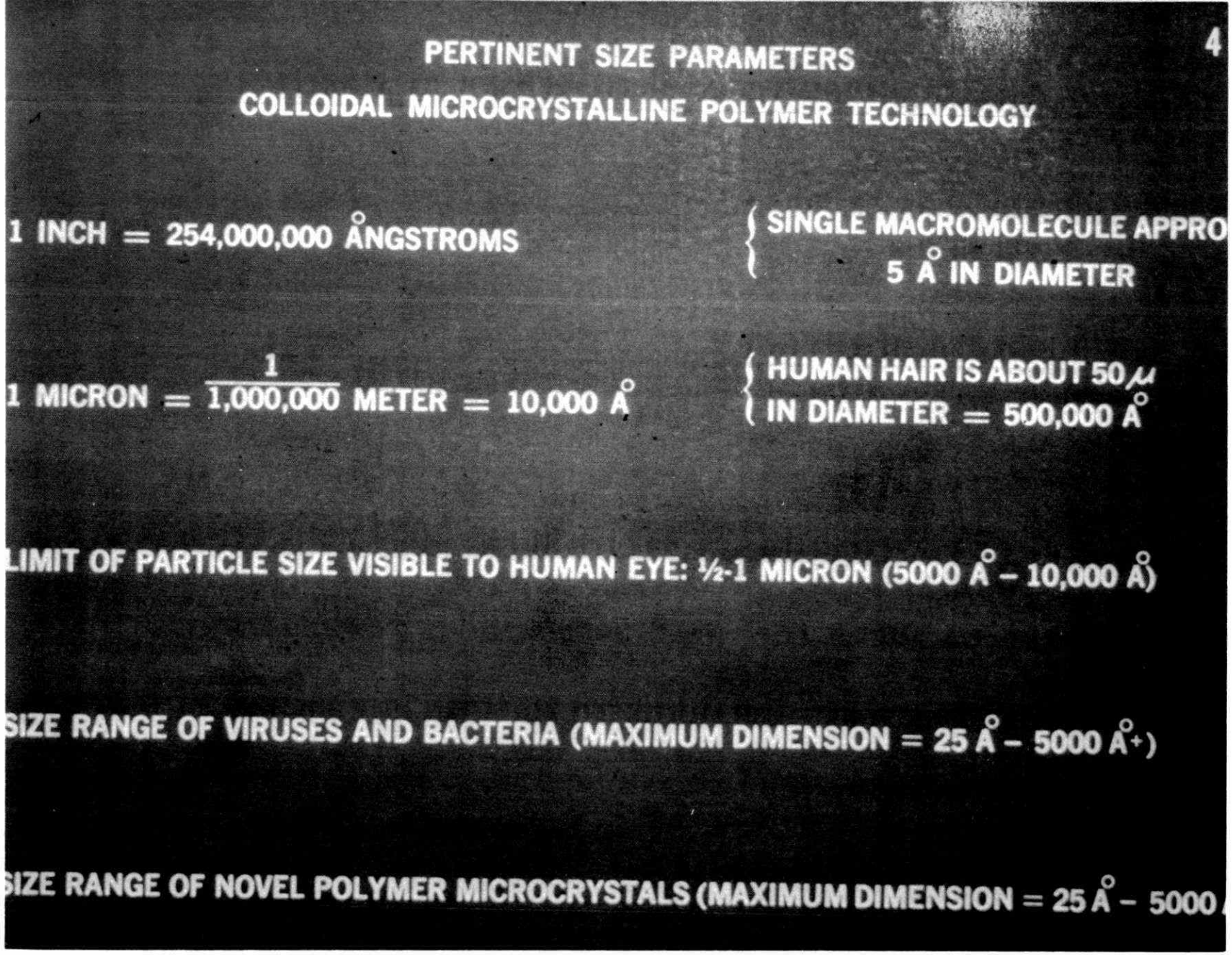

PERTINENT SIZE PARAMETERS
4
COLLOIDAL MICROCRYSTALLINE POLYMER TECHNOLOGY
1 INCH = 254,000,000 ÅNGSTROMS
SINGLE MACROMOLECULE APPRO
5 Å IN DIAMETER
1 MICRON = 1/1,000,000 METER = 10,000 Å
HUMAN HAIR IS ABOUT 50 μ
IN DIAMETER = 500,000 Å
LIMIT OF PARTICLE SIZE VISIBLE TO HUMAN EYE: ½-1 MICRON (5000 Å – 10,000 Å)
SIZE RANGE OF VIRUSES AND BACTERIA (MAXIMUM DIMENSION = 25 Å – 5000 Å+)
SIZE RANGE OF NOVEL POLYMER MICROCRYSTALS (MAXIMUM DIMENSION = 25 Å – 5000

Figure 3. Dimensional Scale
As applied to Polymer
Microcrystals

Figure 4. Beaten Alpha
Cellulose Fibers

pulp using controlled acid hydrolysis until you reach what we call a "level-off degree of polymerization". In the case of wood pulp, this is corresponds to the length of a crystal which is not further shortened by continuing hydrolysis.

The exciting thing about this science is that the size of the crystals is predetermined in almost every case. Celluloses offer exciting unexplored possibilities in this regard. The millions of pounds of microcrystalline cellulose produced commercially to date all have been made from one raw material - wood pulp - in which the microcrystals are about three thousand Angstroms in length. However, if you start with ramie or cotton or unbleached sulphide pulp, or rayon - depending on the precursor cellulose raw material, after treating it with acid to its level-off degree of polymerization, the final size of the microcrystal can be controlled to very uniform lengths.

Even within the family of regenerated fibers (see Figure 5), you can have a family of different crystal lengths. Figure (6) is a magnificent picture at 50 MX of a single fibril of wood pulp alpha cellulose which had been pre-treated so that everyone of the microcrystals had been unhinged. Now, when these fibrils are placed in a Waring blender under high shear, billions of individual microcrystals, which were never before freed, disperse into the water and form colloidal suspension. Observe in Figure (7) single microcrystals leaving their original fibril crystalline matrix (not fibrils). Bond

Form of cellulose	Average basic $\overline{DP}$ range
Natural fibers:	
Ramie, hemp	350–300
Cotton, purified	250–200
Unbleached sulfite wood pulps	400–250
Bleached sulfite pulps	280–200
Bleached sulfate wood pulps	190–140
Mercerized cellulose (18% NaOH at 20°C, 2 h)	90–70
Vibratory-milled wood cellulose	100–80
Regenerated fibers:	
Fortisan	60–40
Textile yarns	50–30
Tire yarns	30–15

Figure 5. Level off DP
Table of Data

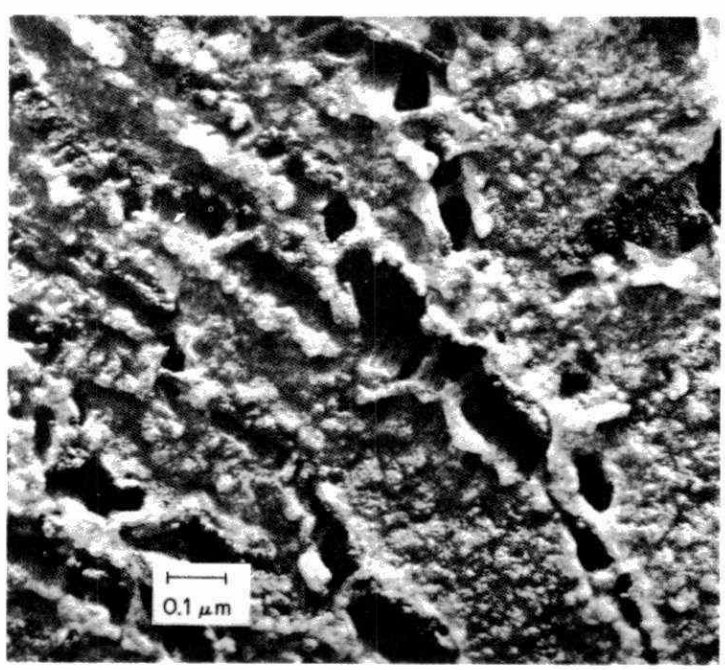


Figure 6. Single Fibril
at its Level-off DP

dispersing into the water medium. As a consequence of the liberation of billions of single microcrystals, billions and billions of new hydroxyl groups are made available to hydrate with molecules of water. As long as they are in the fibril state, tied together laterally by crystalline forces and hinged together, you cannot free these microcrystals no matter how much or how long you mechanically beat them. You must chemically unhinge them to free them to expose this tremendous new surface area.

Figure (8) shows cotton microcrystals at 50MX. They are fatter and more uniform in length that wood pulp microcrystals.

Figure (9) shows rayon tire cord microcrystals. They are little spheres having a diameter of about two hundred Angstroms. When you make a gel of rayon microcrystals, you get a gel that looks more like petroleum jelly than like Crisco or lard because of the smaller size of the microcrystals. The degree of aggregation is also smaller due to the fact they are not long rods that can bond laterally, more tenaciously.

In Figure (10), we compare a clear molecular solution of carboxymethyl cellulose with mechanically pulverized wood pulp, after an hour of attrition in a Waring blender. As long as the crystals in the pulverized cellulose fibers are not <u>chemically</u> unhinged, they will not form a colloidal stable suspensoid; the microcrystals cannot be freed easily until you unhinge them. Theoretically,

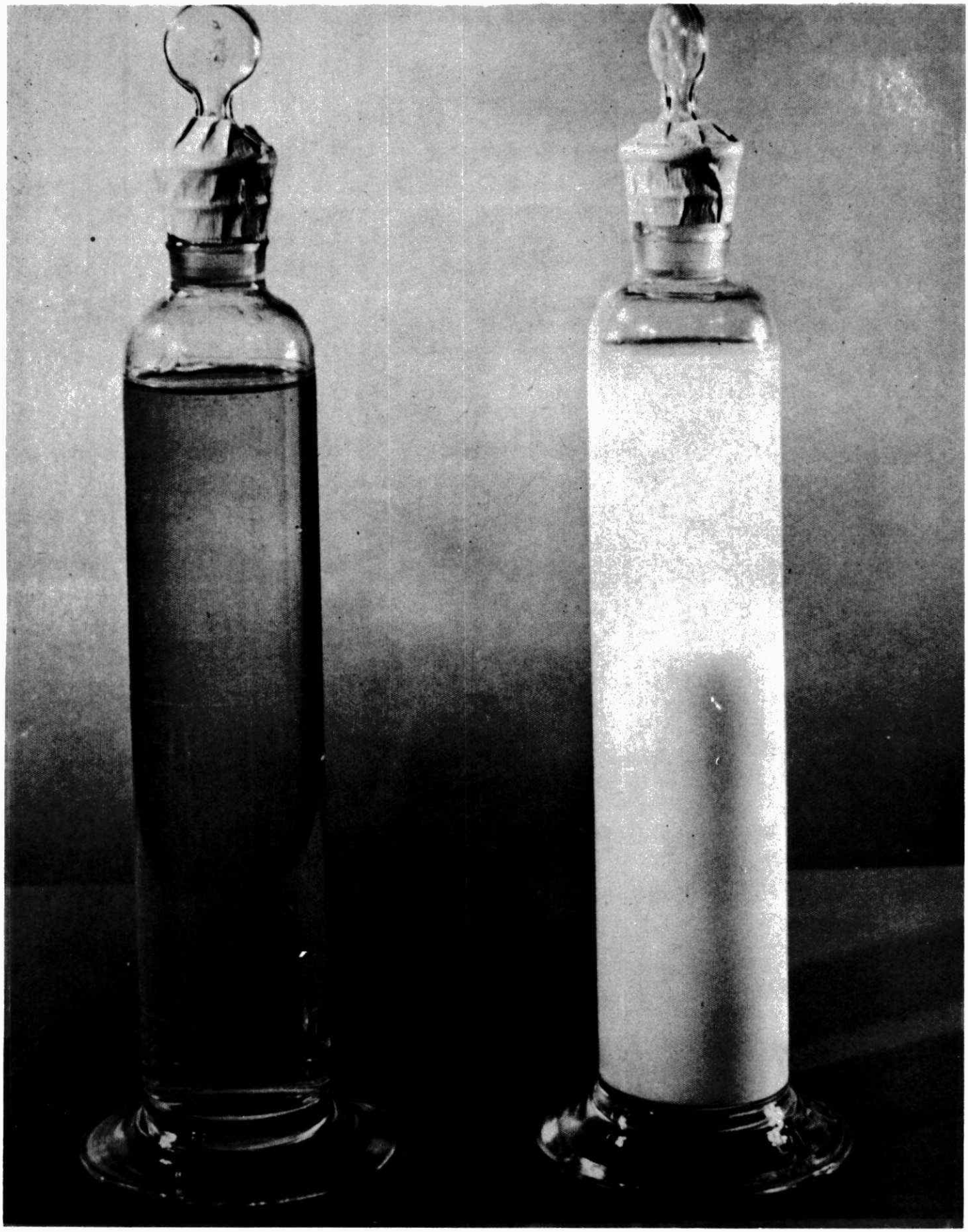


Figure 10. Comparison of CMC Solution
and two phase powdered cellulose
after severe mechanical attrition.

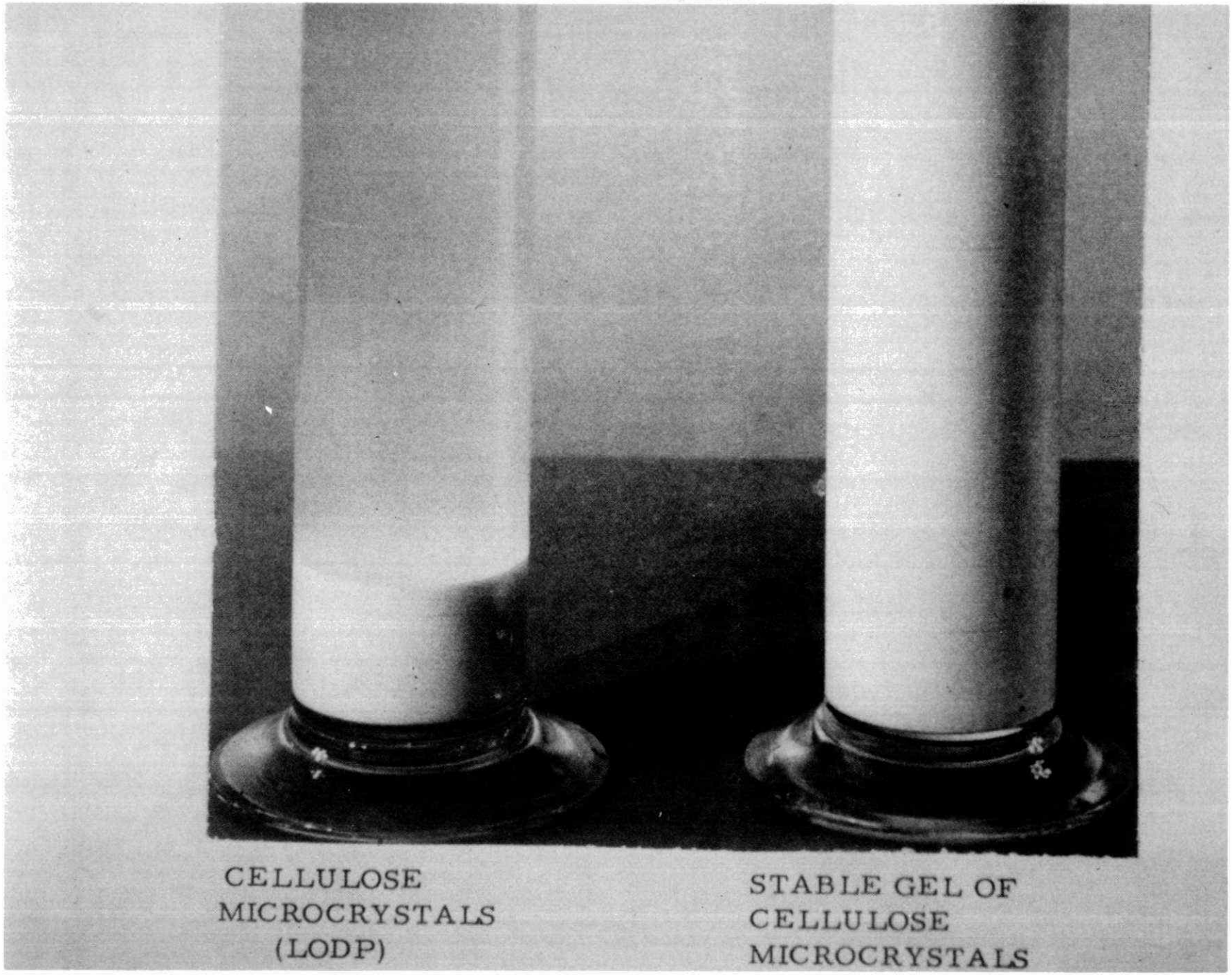


Figure 11. Original Experiment during which cellulose gel was formed

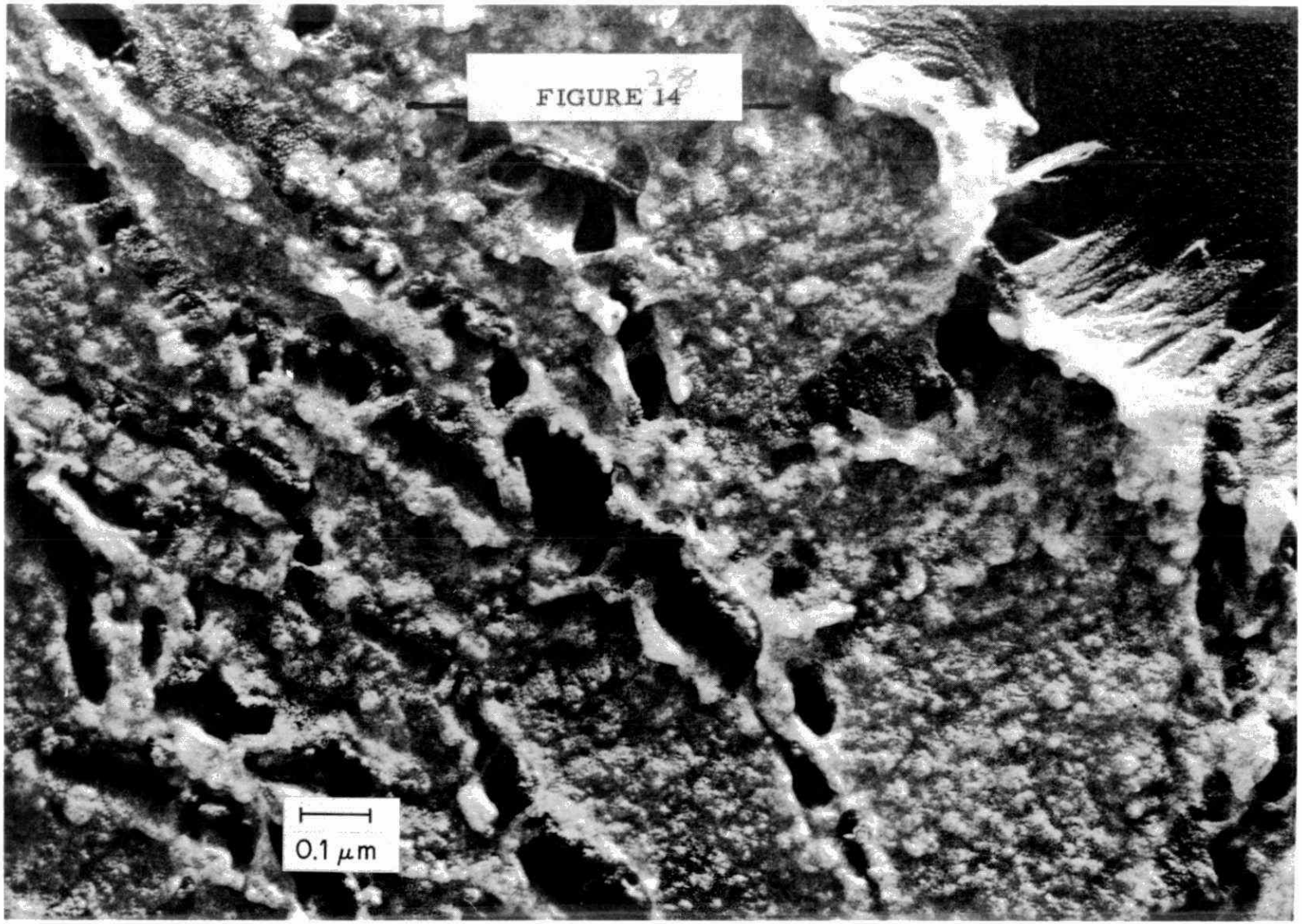


Figure 12. Cross Section of a Single cellulose Fiber at level off D.P.

Figure 14. Three forms of cellulose microcrystals - powder, pourable gel, solid gel.

if you applied enough energy, you could do so but it would require a tremendous amount of energy.

Figure (11) shows the results of the original experiment that was performed in 1955. I kept it for historical reasons. This is the experiment in which unhinged cellulose microcrystals (called level-off D.P. cellulose) when treated in water in a Waring blendor produced a suspensoid which was very stable, and spread like butter. Of course, it was this gel in the Waring blender which represented me with one of the greatest thrills in my life! I knew as a cellulose scientist that man had not done this before and the reason why.

In Figure (12), we show a cross-section (200 MX) of a single fibril of cellulose in which we have unhinged all of the crystals. Note the "holes" where the lignin was before it was removed by the pulping process. Note also how nature has beautifully lined up all the cellulose microcrystals in this fibril, like matchsticks, side-by-side.

The mound of smooth, edible, opaque pure cellulose gel in Figure (14) is the basis upon which the calorie content of many foods is engineered. The human body cannot metabolize cellulose; we have checked this with radioactive tracers as well as microscopically. Microcrystalline cellulose goes through the human body, as best it can be measured, without anything remaining behind; the human being just cannot digest cellulose under normal conditions, at least.

Figure (13) illustrates how once-freed microcrystals, when dried down from a dilute suspension (5-8 per cent) produces new highly porous particles. Each of these colloidal particles (and bear in mind they are magnified 50 MX) is full of holes. The holes are from ten to one hundred Angstroms, depending on how you let the suspended and freed microcrystals reaggregate during the drying step.

Each species of the growing family of microcrystal polymers exists in three forms (Figure): as a dry powder, a heavy pourable cream which is very stable, or at still higher concentration, as a spreadable gel which is moldable.

I want to take a moment here to point out an anecdotal event, about which I am reminded every time I see this photograph! (Figure 14). The laboratory (rayon research) in which this original work was done did not have facilities to handle food products. Nevertheless, and not without some needling by my associates, I started with a spreadable microcrystalline cullulose gel, added salt, carotene dye, and synthetic butter flavour. The result was a product that I could mould and spread like butter. Not only did it look like butter and taste like butter, but it didn't have any oleogenous material in it. It It didn't have a single calorie, it didn't have a single lipid in it. Ergo, I had at hand an imitation butter with zero calories. Excitedly, I took some home to Mrs. Battista. Mrs. Battista made some waffles, and the whole family was so excited. We were going to test this zero-calorie butter on waffles for the first time ever! We spread it on the

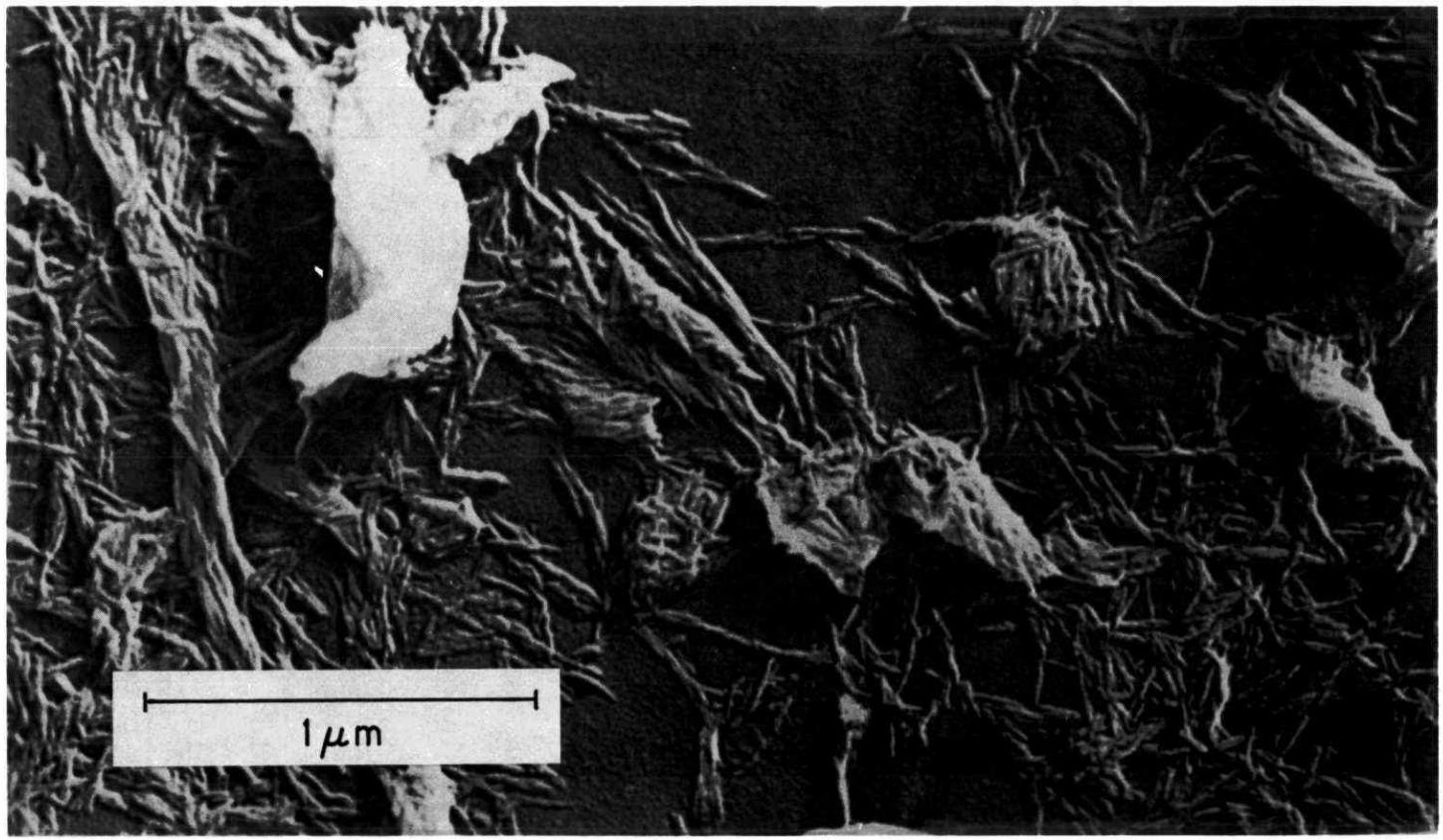


Figure 13. Single Cellulose (wood pulp) microcrystals reaggregated after spray drying

not waffles; it stayed there as solid as ever. It wouldn't melt! We found out later why. Cellulose microcrystals won't melt. Butter is an emulsion of fat globules in water, and the fat globules melt with heat. In the case of our "imitation butter, we had hydrophobic polymer microcrystals hydrated in watet; the physical phenomenon comes out to be almost identical to that of butter. But cellulose microcrystals decompose before they can melt!

In Figure (15), we show the unique rheology of these gel systems. They have a unusual stress-strain shear property. They have a unique yield value.

For example, microcrystalline cellulose suspensoids are used for many particulate drugs in liquid suspension, such as sulfa drugs for children. Sulphanilamide or particulate penicillin can now be dispersed in these edible gels and stored the drugstore shelf for years. Because of the brush heap structure of these suspensoids, the drug particles become trapped in the brush-heap structure and cannot settle - they overpower Stokes law, a very simple side effect of these materials. If you apply shear - stress to these gels, the microcrystals line up like matchsticks and the viscosity drops rapidly. The minute you remove the stress, Brownian motion helps to randomize the microcrystals. They possess unusual thixotropic and pseudo-plastic properties. A very exciting thing about cellulose microcrystals is that gels made from them are insensitive to temperature. For example, the viscosity of these gels at 100 degrees

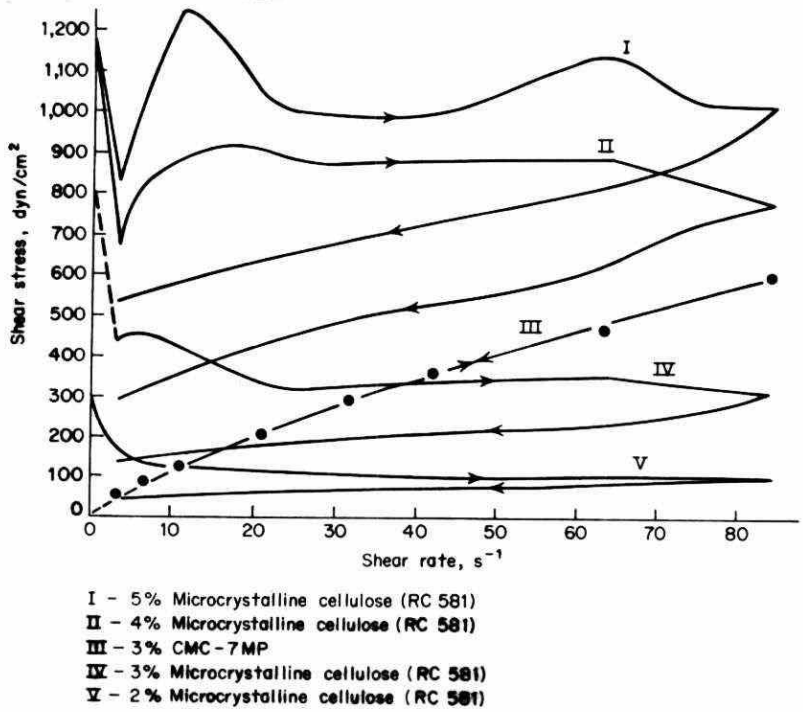


Figure 15. Rheology Behavior of Microcrystal Gels.

centigrade is essentially the same as it is at twenty degrees.

As a result, commercial products (Figure 16) are marketed today taking advantage of these properties. Canned tuna fish, for example, with salad dressing included, and many other precooked products can be prepared using salad dressings based on microcrystalline cellulose gels.

The initial major commercial use for microcrystalline cellulose was one which we had not anticipated: millions of pounds of cellulose microcrystals each year go into pharmaceutical tabletting. Microcrystalline cellulose, because of its crystalline nature, is highly compactable. It serves as an excellent binder to reduce almost to zero the breakage of tablets in the tabletting manufacturing process. More importantly, when you compress microcrystalline cellulose in a vitamin or an asprin or other tablet, the tablet is very durable during shipping, handling, and storage. It won't cause whitening of the bottle when you shake it as the former compositions did. More importantly, when you drink the tablet with water, you break the weak hydrogen-bonding forces that are between the surfaces of a microcrystals during compaction, so that the drug is released in your stomach instantly. Previously used binders would take a much longer time to dissolve and release the contents of the drug into the stomach.

Figure 16. Commercial products containing microcrystalline cellulose

Here is a story of what you might consider was "a waste material" which was upgraded by new science that gave the new colloidal cellulose powder superior performance properties, properties that led it to command about $1.00 a pound while almost totally replacing previously used materials that cost only 15 to 20 cents a pound, clear proof its superior price performance ratio.

Figure (17) shows an interesting phenomena. If you roll this gel at a cottage cheese consistency in equipment such as a Hobart nuxer, surface tension force cause the microcrystals to form into very hard perfect ball-like spheres as the drying proceeds. At UTA we are taking nylon microcrystals and we are making a nylon gel at 10 per cent solids. We are suspending in this gel colloidal gamma alumina. After making these spheres, we drive off the water, calcine the product and we end up with hard gamma alumina catalyst spheres. The holes in the refashioned gamma alumina are uniformly two hundred Angstrom; firing burns out the organic nylon microcrystals which were trapped inside the spheres, leaving holes in their places. Depending, of course, on the size of the microcrystals, you start with, and how well they are inter-dispersed with the alumina, you can now make catalyst spheres of silica or gamma alumina and control the pore size and size distribution almost at will. We believe this has great importance in connection with the energy program and our research is in the direction of producing superior catalyst substrates. The story and the future of microcrystal polymer science have just begun, and one

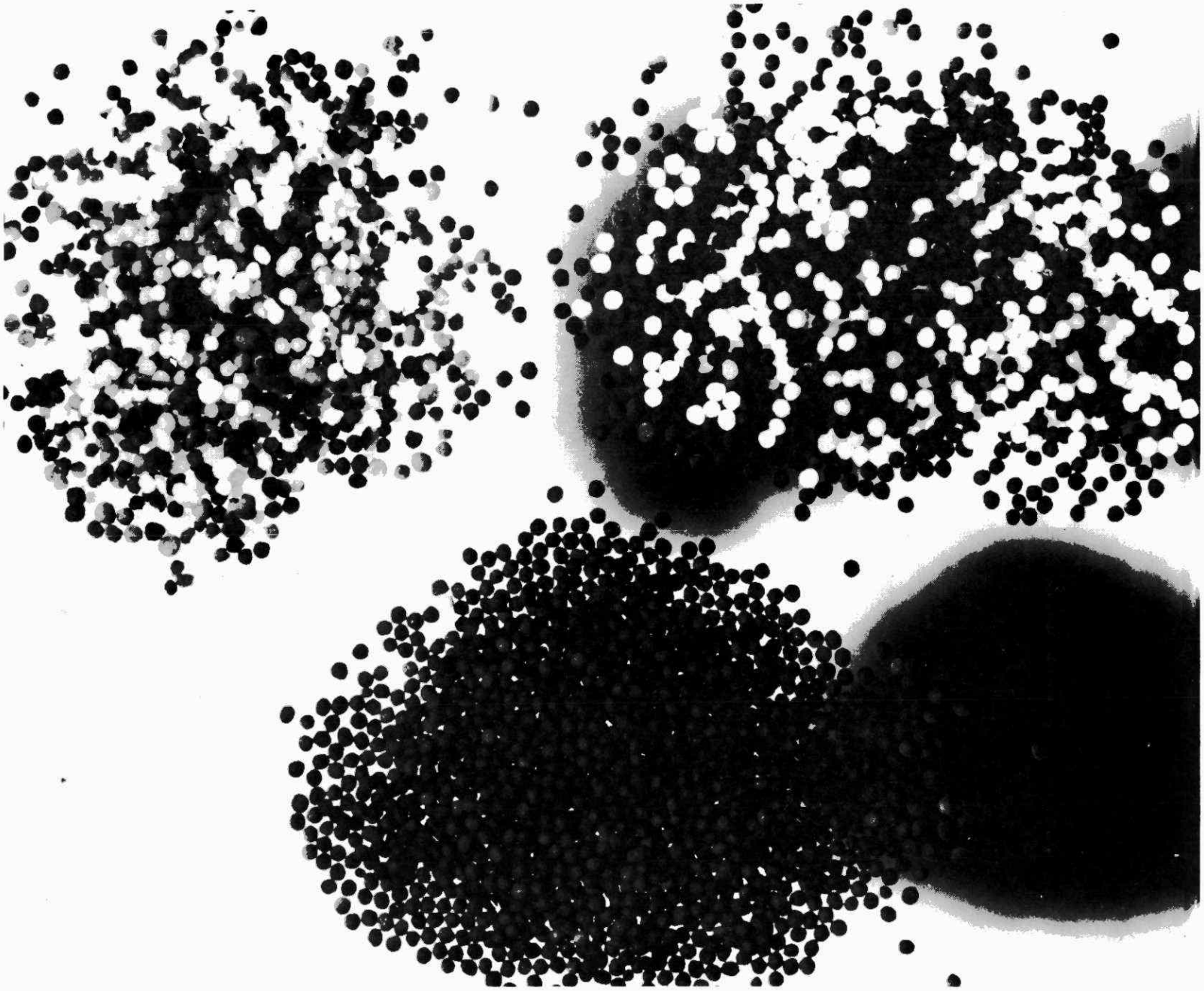


Figure 17. Hard spherical particles of microcrystal cellulose

reason I am here today is because I believe this science can do much to utilize waste fibers in highly upgraded forms.

Question: When we talk about synthetic fiber waste, we also have to talk about impurities, for such waste contains spinfinish, nuts, and bolts, used ball point pens and so forth. Does this affect your process?

Answer: That's a very appropriate question. May I suggest that I answer that in this way. Ten years ago I approached J. P. Stevens, Burlington Mills, and American Viscose, all of whom had lots of waste, but ten years ago was ten years too soon. They also responded by mentioning contaminants. They do present a problem. But the figures that have been shown to us here at this seminar point out that there is available very high poundage of relatively clean waste cotton/rayon blends, cotton/Dacron blends, etc. In those two instances, the process for conversion to the respective microcrystalline forms helps to separate many contaminants, with cotton and rayon blends, both the cotton and the rayon can be hydrolized in the same digester under identical conditions. In the case of cotton and polyester or cotton and nylon blends, it turns out that the hydrolysis conditions for the cotton are much milder than the hydrolysis conditions for the polyester or the nylon. Accordingly, I envision digesting properly the cotton first, and wash out the cotton microcrystals separately, leaving the nylon or polyester fibers behind almost intact. Then, you would digest the remaining polyester or nylon under more severe

conditions and convert them into colloidal microcrystals, in the same digester. The sequence of digesting steps used would be determined by the composition of the raw waste material. Acid digestion and extensive washing would get rid of many contamina. Physical separation would remain for the "nuts and bolts".

Initially you would start with waste materials which are relatively simple and prove the process out and not worry about the products that have too many contaminants or the products which have other materials which would seriously interfere with the salability of the material. Obviously, the application of this new science to waste polymer will have limitations. You will have to pick selectively the particular raw materials to test the viability of this first. The exciting thing is that until now we have been almost exclusively concerned with edible and medical uses of polymer microcrystals. Very little has been done in the industrial area, except that there are growing demands for industrial grades of microcrystalline cellulose, which has been used as a paint thickener, etc.

When you have got waste material you can afford to relax your quality to achieve a lower cost so that you can get it into non-health industrial uses. This would be the real hope that I see for the application of microcrystal polymer science in support of this program.

I would strongly urge all of us to think in terms of picking those fibres and available materials which could be translated into the most profitable products because of their initial purity. You might not be able to touch some of the higher volume mixes and as far as the chemistry is concerned any inorganic contaminant wouldn't hurt. I can tell you that to convert this science into useful products from waste materials will require a champion and a great dedication to overcoming the resistance. Ten years ago I got nowhere with considering waste fibers resistance to new technology. This, however, has been the story of my career and my modest success. Today, the time is right!

ONTARIO MINISTRY OF INDUSTRY & TOURISM

"BETTER UTILIZATION OF TEXTILES"

MICHAEL BRENT - PRINCIPAL

KURT SALMON ASSOCIATES INCORP.

"BETTER UTILIZATION OF TEXTILES"

I would like to start by complementing the organizers of this seminar. The main subject matter is "Utilization of Textile Waste", but by giving me the honour of addressing the subject "Better Utilization of Textiles", the principal of prevention rather than recovery is recognized.

I have been consulting to the apparel industry on material utilization for ten years, and I suppose that if I had done a better job there would be no textile waste and no need for this seminar. However, with very few exceptions, the manufacture of apparel products must result in significant waste at today's level of technology.

How much waste, and the potential for its reduction is my subject.

First, let us review the significance of waste to the

to the average apparel manufacturer. On average, 48 percent of the cost of manufacturing a garment is for the material. Given the importance of material cost to the manufacturer, you would expect him to pay a great deal of attention to maximizing its utilization, but that is most often not the case.

Typically, those of our clients who engage us for a material utilization project save from 3% to 6%, worth 1½ to 3% additional pre-tax profit. Why do so many companies continue to suffer this lost profit opportunity?

The average manager in an apparel factory is beseiged by conflicting demands from all sides:-

- to raise production
- to better quality
- to reduce labor costs
- to pay higher wages
- to speed throughput time

When faced with the problem of excessive material usage (if he is ever actually faced with the problem), he rationalizes the waste by saying that tighter controls or alternative systems would adversely affect performance in one of the other areas. In reality, no-one is pushing

for improved material utilization the way merchandizing is pushing for production and quality, the Union for a wage increase and so on.

How much waste is there? The breakdown of usage for the average apparel product is :

Basic body surface area	45.0%
Other pattern requirements	36.1%
* Minimum marking losses	8.0%
* Planning losses	4.5%
Average size sold too large	2.0%
* Width loss	2.6%
* Spreading loss	1.8%
	100.0%

* These losses go into the scrap bag, totalling approx. 17%.

What is the typical potential for reducing losses?

Other Pattern Requirements (36.1%)

These are for fit and fullness, seams, trim and alterations. A critical appraisal of the need for these allowances will often result in a reduction.

Planning Losses (4.5%)

This is the most neglected area. To mark a single size of garment is generally inefficient. For any given product, there is an optimum number of sizes to mark together for material efficiency, but the number of sizes depends on the style, the actual sizes, and the material width. Of course, merchandising demands a complex mixture of units by size and color. Production planning must decide how to cut those units and try to achieve the most economical cost. But total cost is that for labor and material. The correct plan is the one which minimizes the total. Manufacturers understand this balancing of costs, but rarely apply the correct parameters to arrive at the best solution, working rather by guesswork. Rarely, also, is merchandising questioned to determine whether the original order quantities can be modified in order to yield lower total costs for a slightly different number of units.

Varying piece-goods widths area further complicating factor in the planning process. When should wider piece-goods be cut separately?

The planning process is an ideal application for the computer, and more manufacturers are turning in this direction. Too often, however, they set up their programs

with inaccurate cost parameters.

Marking Losses (8%)

This is the average loss within the marker of the ideal section. Good marking is a skill which the computer has not yet learned to match the better human effort.

Achievement of good marking is essentially a management task, as is the achievement of quality performance by employees in any other area. The keys to attaining performance are :

- setting realistic goals
- measuring performance
- reward

Technologically, miniature marking has been used for years, enabling better performance. In recent years, computerized marking has gone a step further in removing the non-skill elements from marking, allowing the better operators to cover a greater percentage of requirements.

Width Losses (2.6%)

To make the best use of available labor, it is necessary for manufacturers to cut different widths of piece-goods together. Naturally, markers must be made to the narrowest width.

Too often, however, the width of piece-goods is not even measured, and no planning for utilization of width takes place at all.

This is a particular area where textile mills could help to reduce waste. More research should be carried out to determine the optimum piece-goods width for different garment types, and the mills should then try harder to produce consistently to the desired width.

Spreading Losses (1.8%)

Spreading losses occur at the ends of spreads, in damaged pieces cut out, and in the unused end of each roll. There is nothing too complex about controlling these losses. Excessive waste is a result of sloppy management. The textile industry can help, by imposing tighter standards of quality with regard to the number of defects produced.

Overall, we believe that material usage could be reduced from 3 to 5% right across the apparel industry. This may not seem a large figure, but we have already seen that it can mean a 2½% increase in pre-tax profits. More importantly to the subject of this seminar, it means a 20 to 30% reduction in the amount of waste.

Is there any one key to unlock the door of waste reduction? New technologies such as computerized marking have enabled improved performance, and the key word is enabled. They do not automatically result in continuing savings.

The real need is for wasted material to be as conspicuous as wasted labor. Material must shout as loudly as a grieved union steward. But material can't talk, so it must have a human mouth-piece, someone in the organization who has material utilization as one of their prime functions, if not sole responsibility. But who is qualified for such a position, bearing in mind that material is 48% of manufacturing cost? What a staggering responsibility. Does anyone know of a "Vice-President of Material Utilization".

In only rare cases is it either an academic subject or a job position. Yet some of the techniques of controlling material usage are complex, and well worthy of research and academic attention.

In summary, textile waste is about 17% of usage in the apparel industry. Perhaps one-quarter of this is recoverable, but until material utilization is accorded serious recognition as an engineering and management discipline, it will remain the baby-brother of time study and methods engineering, with archaic and wasteful

practices passed down from one generation to another.

Thank you.

MR. ROLF WAGNER

SYNTEX CHEMIE GmbH

FRANKFURT - GERMANY

"BUILDING PRODUCTS FROM CARPET & TEXTILE WASTE"

UTILIZATION OF TEXTILE WASTE SEMINAR

KINGSTON - ONTARIO

MINISTRY OF INDUSTRY & TOURISM

INDUSTRY BRANCH

JUNE 21, 1977

Ladies & Gentlemen

Today it is for me a special concern to thank the government of the province of Ontario and particularly the Ministry for Industry and Tourism who gave me the possibility to speak to you. With pleasure I followed the invitation, because the subject of this seminary already today is of extraordinary importance, and I am sure, it will grow more and more within the nearest future. For possible faults in my English expression I ask for your indulgence.

The subject I selected in this connection especially concerns the reprocessing of remainders from the carpet-producing industry, but also from industries, where chemically bonded textile structures are produced.

Preferably on the production of carpets according to the tufting process extremely large quantities of voluminous remainder are obtained, remainder for which - until now - no recycling process with optimum application possibilities was found. The consequence of this fact was that about 2 years ago considerations were started to develop a continuous process to find for these remainders a reasonable and suggestive reusage.

As I already mentioned before this process is based on remainders from the tufting carpet industry and on such

from the non-woven field. Here it must be mentioned that the remainders from the field of tufting carpet industry generally consist of several fibre components and are bonded with chemical substances, such as latex, PVC, and Polyurethane.

As to the remainders from the field of non-woven production in particular chemically bonded materials are of importance. Most usually these remainders are brought to waste dumps. The quantities per year, which are obtained in this field of industry are extremely high, so that for instance the figure we have for the Federal Republic of Germany was for 1976 almost 30,000 tons. In the area of the European community the today's total amount of remainder from these fields of production is estimated to be abt. 90,000 until 100,000 tons, even not yet considering remainders from the production of hard-floor coverings.

For the future a further increase of these production remainders is expected, since the statistical prognosis for the year 1978 indicates a production increase of abt. 22%. From observations we know that in a fully integrated carpet manufacturing plant the total amount of waste can be up to 12%. This amount includes abt. 5 - 8% of edge trimming depending on width of fabric, and 3 - 5% of off-cuts.

Since the remainder material is extraordinarily voluminous - the approximate bulk density is about 0.1 - 0.2 - you easily can imagine, which dump capacity will be necessary to store these remainder quantities. And in this connection special attention must be paid to the fact that this remainder material mostly consists of synthetic substances and therefore does not rot.

Therefore, the idea to reprocess these remainders in one way or another, becomes imperative. Tests to crack these materials by means of pyroly sis must be given up, because this way proved to be too energy-intensive and thus not economical. Burning in waste incineration plants causes greatest difficulties, as the incineration gases are extremely aggressive. The construction and building of acceptable incineration plants, therefore, would means considerable cost increase. Moreover, it must be expected that also the impairment of environment - caused by these gases - in future will not be accepted.

Other tests to reprocess for instance these remainders by means of extrusion also were disappointing, since the composition of the remainders is too nonuniform and since moreover the partially existing native fibre material does not allow a troublefree extrusion procedure. Duly considering all these points of view only a mechanical

recycling process could bring a reasonable solution. In this connection now it was important to concentrate the attention to the fields of application for a possible remainder product.

Basing on the structure of the remainders a special possibility offer the fields of heat and sound insulation.

The process, about which I am now going to give you some details, allows to reprocess the remainders by a continuous procedure to platelike products. By means of a flowsheet I now want to show you the previous and most important process steps:

Item 1 indicates the storing section for the various types of remainder. Here special attention must be paid to the fact that the various remainder components are composed and mixed in such a way that over a longer time a uniform composition of the material to be mixed will be guaranteed. For this purpose the variable metering device, item 2) is provided. The material to be mixed then in its final composition is passed to the collecting conveyer, item 3. This blended material is passed to a cutting mill, where it is cut corresponding to the required end quality. Subsequently by a pneumatic

conveying system, item 5, the material is transported to a mixer, item 8).

This mixer is one of the most important aggregates for this process, since here the material is very uniformly mixed with a binding agent. It is only the very uniform application of the binding agent, which allows to reduce the portion of binding agent to a minimum.

From the mixer the material is passed to the material delivery system, item 11. By means of this material delivery system the mixed material is uniformly and continuously conveyed to a double-band conveying press. In this press the still voluminous material is compressed, and the obtained density must correspond to the later purpose of application.

For this reason it is possible to variably adjust the pressure until 25 kg/cm^2.

For insulation material lower densities should be obtained, but for the product to be used for higher load, as for instance steps' sound insulation on the field of floors high material densities are necessary.

About further fields of application and the possibility to use other production remainders than these already

mentioned before I shall give you more details later.

After having left the pressing section, item 12) after a curing time of abt. 3 minutes for the purpose of hardening out of the binding agent, the compressed material passes the duration zone, item 13. The endless material band then is automatically cut to the desired length and piled on pallets. The standard widths of material usual in the European area are 500 and/or 1000 mm.

As I already mentioned before the application possibilities for this plate material are extremely manifold. Results are available, amongst others, for the following fields:

1) Sound and heat insulation,(and here in particular in the range of insulation for building construction). On the foto you can see the plate as heat and sound insulation for the field of floors, and the foto, which now follows shows the material as sound and heat insulation for doors in houses.

2) In the range of construction of houses the material prefabricated in laminated form can successfully be used as prefabricated unit, and here I particularly

want to point out that this material can be handled with conventional tools. In this connection please see the two following fotos.

As a matter of fact more fields of usage are possible, and I only want to mention for instance insulations for front walls and roofs, covering hoods for noisy machines and insulation for heat conducting pipes.

Recently test runs showed that this material with much success can also be used as sound insulation in the automobile industry and that preferably, if remainder material from the foam production will be used. And these types of remainder material are obtained in particular from the automotive industry, e.g. those from the upholstery manufacture and from the field of dressing (covering) for instrument boards and body.

Here it happens for the first time, that the producer of remainder material can be the consumer of the later processed remainders at the same time. Within shortest time the disclosure of another field of application can be expected, and here it deals about a product for the construction of modern stables, preferably for cattle breeding. For this purpose the recycled material will be used as heat insulation for walls and roofs. In this connection it is of very important advantage that the fibrous surface avoids the formation of condensate. And

here additionally an impregnating agent can be applied without difficulties, and these damages, done by mice be avoided.

In the table I now want to show you some data which were compiled to inform you about the most important properties of the product. But, please, I have to point out that these properties certainly can vary depending on the use remainder material and the process parameter. From the comparison of the data you can see that the values of foamed polysterene cannot be obtained, a fact, which was expected from the first, since it is generally know that polysterene is one of the best insulating material.

But compared with other insulating material, such as mineral wool, mixture of wood chips and asbestos cement and so forth, the values are much better.

I want to take this opportunity to point out another considerable advantage of this material. Compared to chip board - a material which today is mostly used for the manufacture of prefabricated parts. The recycled product obtained by the described process also after a complete saturation with water remains absolutely stable in its dimensions, and once absorbed

humidity within short time will be given out without change of dimensions.

Moreover the mechanical resistance against shock load is extremely good. Finally it must be mentioned that these products, as a matter of fact, can be prepared as fire retarding material, so that there are no difficulties to also use them for the range of building construction.

Reservedly however, I must say, that an examination with the analysis methods, they are usually in your country, up to now was not yet made. But since recently made tests showed that glass fiber wastes without any difficulties can be added up to 20%, this would mean that the possibility of a fire retarding preparation can only be improved.

Since costs and economy are not less important, now I want to give you some details to this point by an example. Basing on the fact that - depending on the locality of the remainder - producing factory - dumping costs of abt. $40.00 per each ton must be paid and the costs for removal and transport will be abt. $40.00 per ton. This would mean from the first already a credit for the manufacturing costs of $80.00 per ton.

With an average content of binding agent of abt. 10%

and the usual depreciation costs for machinery and building and the costs for personnel the amount of manufacturing costs would be abt. $250.00 each ton. If now the credit of $80.00 is reduced the real production costs would be $170.00 per ton.

Basing on a material weight of our insulation plate of approx. 4 kg/m^2 together with the figures I mentioned before a price per m^2 of abt. $0.68 would result.

Because of the great importance the remainder reprocessing in connection with the protection of environment in future will have, such reprocessing projects are financially supported by the European Community and the individual countries being member of the Community. How far this applies to your country I unfortunately don't know.

The high degree of importance this process enjoyed by the past at the government of the Federal Republic of Germany, can be underlined by the fact that the further development is financially supported and that we newly participate in a research work for our government in the field of remainder reprocessing. All the considerations I made until this point do however not yet include a very important aspect about which I want to say some words before coming to the end of my report.

If we take into consideration that the textile floor coverings have an average life time of abt. 10 years within the nearest future a further increase of the remainder material to be reprocessed can be expected due to the then resulting renewal requirements.

I tried to give you some details about the possibilities we have on the field of reprocessing, and I would be very glad if my report would be a helpful contribution to start the discussion about the problems of the remainder recycling and their solution, so that in future valuable production remainders can find a significant reusage and future national economical interests be met.

Thank you very much for your attention.

Properties of Various Heat Insulation Plates

	After DIN	Values of Comparison: Isolation Plate SYNTEX soft	Construction Plate SYNTEX hard	Polystyrol Foam Plate	Wood Fiber Cement Construction Plate
Plate thickness mm		20	20	20	20
Weight kg/m^3	53420	300	1000	33	400
Weight kg/m^2		6	20	0.66	8
Conductivity of heat $\frac{kcal}{m\ h\ c}$	52612	0.04	0.064	0.035	0.08
Tenacity 20°C kp/cm	53455	0.8	1.7	3.8 - 5.5	*
Bending strength 20°C kp/cm^2 -30°C	53452	1.0	2.8	3.5 - 5.0	* *
E-Module kp/cm^2 20°C	53452	30	60	*	*
-30°C		75	120	-	-
Absorption of water after 7 days: Weight %	53421	28	9.9	0.6	-
Change of dimension for water absorption	54318	1%	1%	- *	- *

* Values not known

INFORMATION

RECYCLING
of waste material
from carpet, non wovens
and plastics

SYNTEX CHEMIE GMBH

INTRODUCTION

The urgent need for environmental protection and the recycling of waste material associated with this problem have long since urged us to develop a plant to deal with this situation.

The fact that large quantities of waste material accumulate every day from the production of textiles, nonwovens and floor covering triggered off new ideas. In the Federal Republic of Germany alone, the quantity of waste material from these industries amounted to 25,700 tons in 1973 which is the equivalent of a load of 20,000 railway wagons. Such enormous quantities of re-usable "raw materials" naturally call for diversified and highly reliable processing plants.

The present plant meets these requirements in every respect and has been specifically designed for the processing of textile, floor covering, carpet and nonwoven wastes.

Types of waste material

When manufacturing carpets on a large-scale, wastage of edges, faulty lots, beginning and end sections (heads and tails) is inevitable. This sort of "waste" mainly occurs after impregnation and the application of backings. So far, however, a process offering an economic solution to the recovery problem has not yet been discovered.

In general, all fibres utilized in the manufacture of such commodities are based on man-made materials and are, therefore, not so readily subject to decomposition. The binding agents and adhesives applied are long-life plastics. Backings are also made from plastic.

Particular emphasis has been given to the re-cycling of the following types of waste:

Edges, faulty lots, heads, tails and shearing dust, all of which accumulates during the production of needle felt, tufted carpets, filter and nonwoven materials.

The following quantities of waste material can be expected from a production plant:

a)	Edges depending on production width	5 - 15 %
b)	Produce of inferior quality	3 - 5 %
c)	Punchings depending on punching standards	3 - 6 %
d)	Shearing dust	
Summary from a), b), c), and d) averages		12 - 15 %

Possibilities of re-use

In order to process or re-use such wastage a certain amount of preparation is necessary. The dimensions of the waste material are as follows:

Edges	width :	10 - 200 mm
	length:	5 - 1,000 mm
Material of inferior quality, heads and tails	width :	500 - 5,000 mm
	length:	1 - 300 m

The waste material has to be cut down to the required size, as the efficiency of the recovery process depends on the uniformity of the material used.

To achieve uniformity the different waste materials either have to be carefully sorted or they have to be turned into a homogeneous blend. The waste material is also sorted or blended according to weight and quality.

This waste material can be used to produce:

1. Sheet-type material
2. Slabs, building blocks, bales
3. Moulded material, such as cover hoods

These end-products should be produced discontinuously or, better, continuously. *

Application

1. Insulating sheeting for sound-proofing and thermal insulation
2. Insulating sheets laminated on one or both sides
3. Prefabricated structural elements such as partitions with or without laminated surfaces
4. Furniture elements with the same or different lamination on both sides
5. Prefabricated elements for prefabricated homes, e.g. casings for shutter screens, doors
6. Parts used in road building, such as foundation slabs
7. Slabs or stones to absorb vibration
8. Covers for high-noise level machinery

* We now introduce the continuous process.

9. Insulation moulds for canals, plumbing systems, plant-apparatus, boilers and automobile construction as thermal or sound insulation

10. Floor slabs with laminated carpeting

11. Foundation insulating slabs

12. Building blocks to replace bricks

13. Packing materials, pallet plates

14. Doors and partitions

15. Reinforced supporting elements for machine and building construction and civil engineering

16. Facade and insulating slabs

17. Roofing material, suitably laminated

If necessary, these products can be made fire-retardant.

Process Description

After delivery the carpet waste is shredded to a pre-determined size. The shredded material is then transported to a dosing feeder and then into a mixer. Then the bonding agent is added to the material.

The blended component is uniformly distributed in front of the double moulding belt. This belt system compresses the material to a pre-determined thickness. Moulding pressure, the time the process takes, and temperature are parameters determining the quality of the product.

Lamination of the material, on both sides if required, is carried out simultaneously as the material reaches the moulding belt.

After leaving the moulding belt the sheets of material are cut to commercial sizes by a saw accompaying the delivered product. The accumulating waste is sucked up and re-cycled to the cutting mill. After cutting, the slabs are deposited with the aid of a stacker onto a pallet, where cooling and final curing can take place, depending on the chemical reactions.

On the flow sheet the process steps are shown.

Example for the capacity

For a standard product of 600 mm width, a thickness of 20 mm and a gravity of 0.65, the capacity per hour will be

approx. 930 kg/h

This figure is based on a binder content of 10% and a production speed of 2m/min.

Example to calculate the capacity per hour:

$$\frac{\text{width (mm) x thickness (mm) x V/min x gravity x 60}}{1{,}000} = \text{kg/h}$$

For this process patents are applied for in the following countries:

Germany	Nr.	P 2457848.1
Italy	Nr.	29906/775
England	Nr.	50238/75
France	Nr.	7536844
USA	Nr.	637467
Japan	Nr.	143804/75

Possibilities to design a plant

The moulding press can be delivered in widths of 600 mm and 1,200 mm. The thickness of the product can be adjusted between 8 - 50 mm. Upon request, the material can be laminated on one or both sides. However, in each case it is necessary that the design is adapted to the specifications. A semi-production line is available for this purpose. Trials may be carried out on this unit.

Advantages of Process

The process described above is advantageous in the following ways:

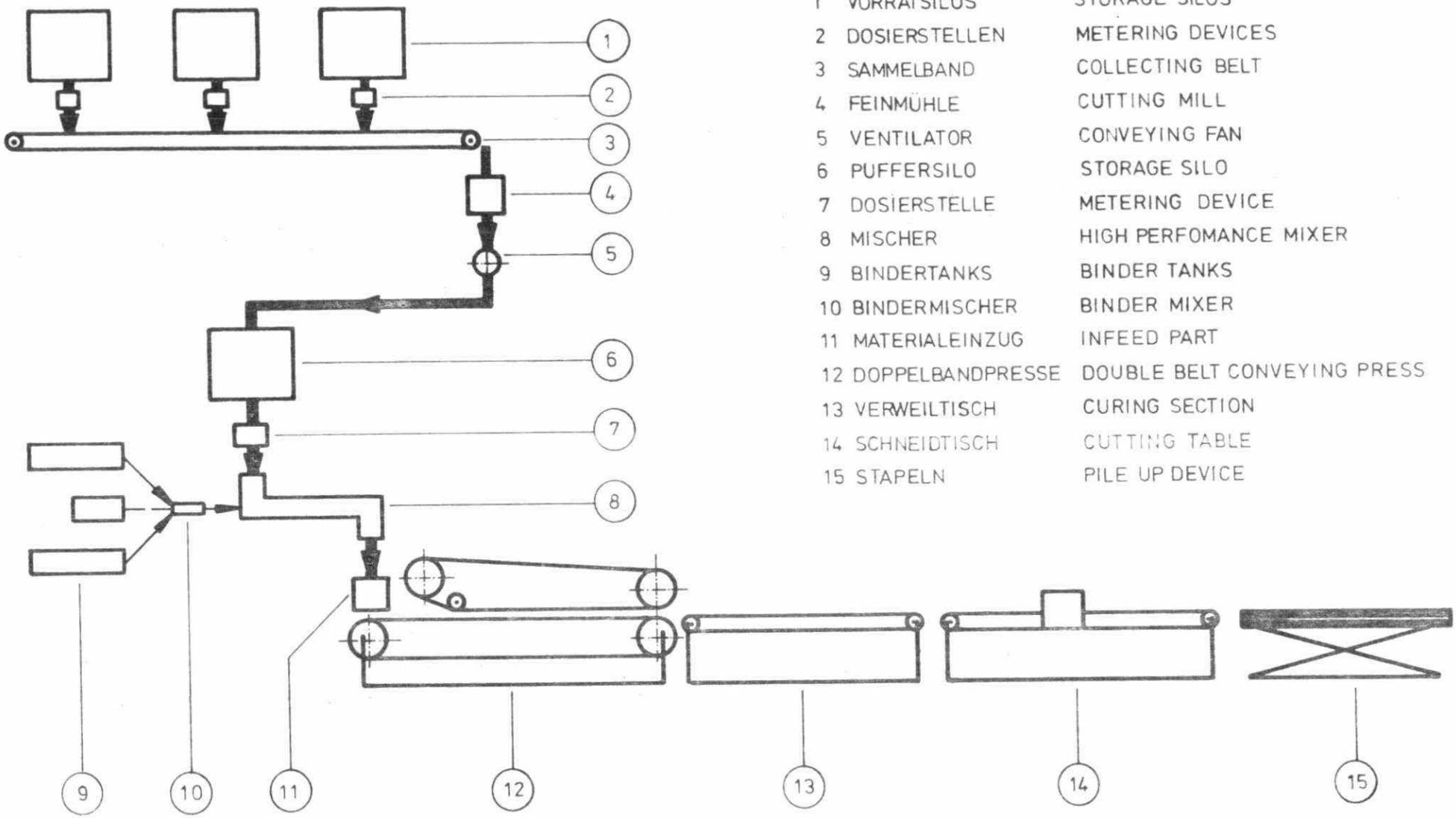
- Waste material is utilized in such a way as to make it environmentally acceptable
- The process engineering is simple and efficient
- The energy requirements are low
- The use of waste results in low raw material costs
- Minimal personnel requirements owing to simple operation
- Low investment costs
- Practical re-cycling of production waste which otherwise would be costly to dispose of
- Overall production increases if the company processes its own waste

Comparison of thermal conductivity of various insulating materials

PU-foam slab	0.015
Styropur	0.027
Mineral wool	0.035
Heraklith slab	0.08
Brick	1.8
Material manufactured according to the process described, measured	0.021 *

The thermal conductivity was determined according to DIN 4108/4109.

* Fluctuations are possible depending on the thickness of the slab and the type of waste material used.



1	VORRATSILOS	STORAGE SILOS
2	DOSIERSTELLEN	METERING DEVICES
3	SAMMELBAND	COLLECTING BELT
4	FEINMÜHLE	CUTTING MILL
5	VENTILATOR	CONVEYING FAN
6	PUFFERSILO	STORAGE SILO
7	DOSIERSTELLE	METERING DEVICE
8	MISCHER	HIGH PERFOMANCE MIXER
9	BINDERTANKS	BINDER TANKS
10	BINDERMISCHER	BINDER MIXER
11	MATERIALEINZUG	INFEED PART
12	DOPPELBANDPRESSE	DOUBLE BELT CONVEYING PRESS
13	VERWEILTISCH	CURING SECTION
14	SCHNEIDTISCH	CUTTING TABLE
15	STAPELN	PILE UP DEVICE

SYNTEX

HERSTELLUNG VON ISOLIER-UND SCHALLDÄMMPLATTEN

SYSTEM LESTI

MANUFACTURE OF INSULATION AND SOUND ABSORPTION SHEETS

WIPERS FROM WASTE

Presented By

Mr. Cliff Palm

Omnitex Inc.

Charlotte, North Carolina

WIPERS FROM WASTE

Mr. Cliff Palm of Omnitex, Inc., based in Charlotte, North Carolina, presented a talk on the development of stitch knitting for the production of non-wovens.

Although a transcript of his remarks is not available, we have prepared an extract from his presentation. Mr. Palm opened by describing his connection with the textile machinery business and the non-woven stitch knitting technology in particular, which had developed in Czechoslovakia.

This technique, utilizing a fleece of regenerated or new fibres which are mechanically interlocked into a non-woven fabric, is capable of producing materials suitable for a whole range of end uses from home furnishings, outerwear, shoe linings, sanitary products to underwear, etc. Utilizing the Arachne Equipment, firms in Europe have been producing wipers from textile wastes.

A description of the equipment follows:

Arachne

The latest world development in the field of textile technology is the production of non-wovens. Czechoslovak textile engineering is not lagging behind this youngest section of textile production. High productivity, possibilities of versatile exploitation, economy of labour and

automation of textile plants - these are the main advantages of the latest technology of producing non-wovens by stitch-knitting the fleece according to an original Czechoslovak patent.

Arachne

The Czechoslovak Arachne 18 stitch-knitting machine represents a new technique to be widely applied in diffrerent manufacturing branches, such as the knitting, cotton, wool and linen industries, as well as in the processing of new man-made fibres.

The wide field of application of this machine and the whole new technology is being made possible by the non-wovens produced on the Arachne stich-knitting machine which has, besides the normal mechanical properties, a substantially lower weight and higher heat-insulating capacity than woven fabric. Whereas no local thickening of fibres by means of classic thread interlacing or chemical bonding agents used in some processes of producing non-wovens, occurs.

The new technology has found application due to the high quality and utility value of the end products, and especially by lower production costs, most of all in the field of the production of heat-insulating cloth, industrial and special purpose fabrics. The Arachne 18 stitch-knitting machine with its production range can be used in all branches of the textile industry. This technology enables the production of a wide range of articles, such as:

1. Stitch-knitted fabrics for industrial end-uses with the possibility of application in the garment and shoe industry as packing cloths, backing fabrics for synthetic leather, stitch-knitted fabrics for heat- and sound-insulation, filtering cloths, etc.

2. Home furnishings: decorative fabrics, carpet and runner backings, table cloths, linoleum backings, blankets, etc.

3. Stitch-knitted fabrics for outerwear: ladies' and children's coats, cardigans, jackets, ladies' and children's dresses, beachwear and loungewear.

4. Stitch-knitted fabrics for the shoe industry to make textile footwear, foot easers for rubber boots; shoe linings and other products.

5. Stitch-knitted fabrics to be used as floor coverings with loop surface.

6. Stitch-knitted fabrics for sanitary width, rib and bandages of different width, stitch-knitted fabrics for underwear, etc.

The classic production process of textile fabrics consists of a great number of operations which are necessary to produce the yarn and the product. Most of these operations are extraordinarily hard and require several expensive machines of exacting operation. The classic production method thus becomes time exacting and costly.

The realization of the new Arachne technology solved the problem of systematically shortening the textiles production process. The progressive technology of stitch-knitting fleeces on the Arachne 18 stitch-knitting machine replaces the weaving and preparation of weaving, usually

the lengthiest operation of spinning. The basic product is the fleece of loosely arranged fibres which are reinforced by stitch-knitting. The yarn used for the stitch-knitting makes 3 to 35 percent of the total weight of the stitch-knitted fabric. When using man-made filament fibres in the warp, no spinning whatever is necessary.

Arabeva stitch-knitting machine is the most up-to-date machine to produce mechanically interlocked non-wovens without using binding threads.

The Arabeva technology consists of reinforcing the fleece by stitches formed directly from the fibres of the reinforced fleece.

Stitch-knitted fabrics produced by the Arabeva technology are characterized by good heat-and sound-insulating properties. They are used as heat-insulating interlinings in the garment industry, in the production of elastic interlinings for garments, as backings for the production of heat- and sound-insulating floor coverings, as supporting interlining or backing for needle punched products, e.g. napped linings, blankets finished by setting the pile and other items.

Description

The Arabeva equipment can be simply mounted on the Arachne stitch-knitting machine. The adaption of the Arachne machine for the Arabeva technology requires:

1. stopping the movement of the closing table
2. putting the guide bars out of action
3. special basic machine equipment
4. using reinforced working needles
5. filling sinkers

Principles of the Arabeva Technology

The fleece with fibres orientated crosswise to the fleece length is fed into the Arachne stitch-knitting machine, equipped with the Arabeva device.

The working needles pierce the fleece when moving into the forward direction. The stitches which have been formed in the foregoing course, remain on the needle shanks.

When the working needles move backwards, the hooks of the needles piercing the fleece are filled with a certain amount of fibres by means of a special device.

In the following stage the hooks of the working needles are closed by the needle latches, the fibres placed into the needle hooks are drawn through the remaining layers of the fleece and the old stitches, thus form new stitches. The stitches are mutually interlaced in the form of chain-stitch and ensure the strength of the stitch-knitted fabric in the lengthwise direction. The crosswise strength depends on the length of the fibres in the fleece, the fibres being orientated in the fleece in the same direction.

Suitable Materials for the Arabeva Technology

Besides the usual fibres it is possible to process different kinds of regenerated textile fibres, e.g. semi-wool, rayon, cotton waste, jute fibres and tow. In order to accomplish the required strength of the stitch-knitted fabric, the blend has to contain at least 20 percent of fibres other than 40 mm. In order to achieve a better filling of the stitches, coarser yarns, e.g. 6.5 denier and more, are the most suitable. It is possible to

process the fleece from the lap, or the Arachne machine can be aggregated to the fleece-forming equipment.

Advantages of the Arabeva Machine and Technology

1. The stitch-knitting machines

   Arachne 18 working width . . . 1800 mm

   Arachne 25 working width . . . 2500 mm

   can be easily supplemented by the Arabeva technology device.

2. The Arabeva technology enables the range of stitch-knitted fabrics produced on the Arachne machines to be extended.

3. No yarns are used when producing Arabeva stitch-knitted fabrics.
   (a) no preparation of binding yarn is necessary
   (b) machine efficiency is increased up to 80 percent
   (c) the production of Arabeva stitch-knitted fabrics is extraordinarily economic.

4. The device is simple, easy to understand and reliable.

To utilize this system in the possible conversion of waste into wipers it will, of course, require the use of certain preparatory equipment to convert the waste cuttings etc. into fibre by garnetting, carding equipment together with cross-lapping equipment.

There are two avenues of approach in the conversion of waste into wipers. The first would include the use of a light substrate of woven material into which the layer of prepared waste fibres are stitch bonded

by the Arachne machine. In this case the waste material would amount to 70 percent with the remainder being the backing.

In the second instance, by using the Arabeva approach, no backing substrate or stitch yarn is required and the fibres in the material being converted act as the stitching medium itself. It is interesting to note that in Czechoslovakia itself, up to 30 percent of the Arachne type machines are used in the conversion of waste textile material into wiping and other types of material.

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